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PB-284 925

Separation of Algal Cells from Wastewater Lagoon Effluents. Volume I. Intermittent Sand Filtration to Upgrade Waste Stabilization Lagoon Effluent

Utah Water Research Lab, Logan

Prepared for

Municipal Environmental Research Lab, Cincinnati, Ohio

Jun 78

United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/2-78-033
June 1978

Research and Development

PB 284 925

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Separation of Algal Cells From Wastewater Lagoon Effluents

Volume I: Intermittent Sand Filtration to Upgrade Waste Stabilization Lagoon Effluent

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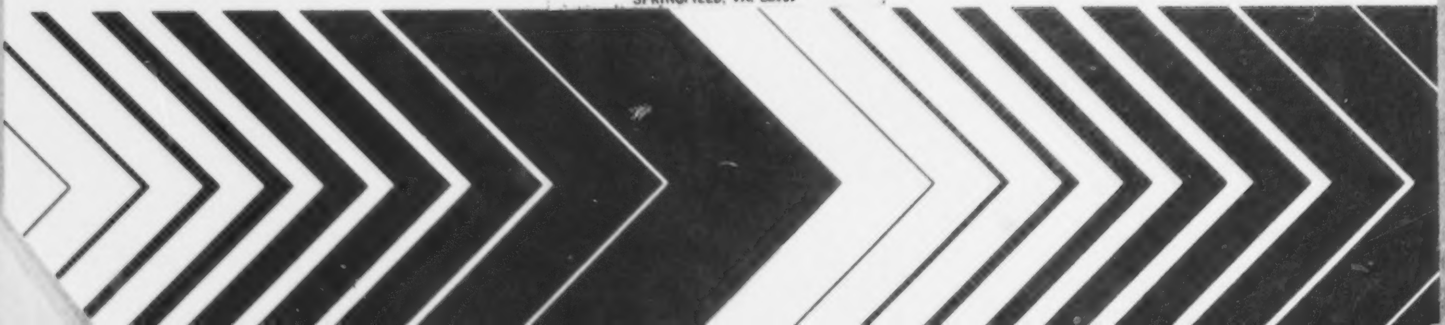

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TECHNICAL REPORT DATA
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1. REPORT NO. EPA-600/2-78-033	2.	3. RECIPIENT'S ACCESSION NO. PB284925
4. TITLE AND SUBTITLE SEPARATION OF ALGAL CELLS FROM WASTEWATER LAGOON EFFLUENTS; Volume I: Intermittent Sand Filtration to Upgrade Waste Stabilization Lagoon Effluent		5. REPORT DATE June 1978 (Issuing Date) 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Steven E. Harris, D.S. Filip, James H. Reynolds, E. Joe Middlebrooks		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Utah State University Utah Water Research Laboratory Logan, Utah 84322		10. PROGRAM ELEMENT NO. IBC611 , SOS#3, Task D-19 11. CONTRACT/GRANT NO. 68-03-0281
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory--Cin.,OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final 1973-1977 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: Ronald F. Lewis 513/684-7644

16. ABSTRACT

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It was concluded that the intermittent sand filter is an ideal process for upgrading lagoon effluents.

This report was submitted in partial fulfillment of Contract No. 68-03-0281 by Utah State University under the sponsorship of the U.S. Environmental Protection Agency. Experimental work described and discussed herein covers the period of July, 1974, to July, 1975.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Waste treatment *Lagoons (ponds) *Sand filtration *Algae Effluents--filtration	Intermittent sand filtration Algae removal	13B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 194
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE A09- A01

EPA Form 2220-1 (Rev. 4-77)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1978 — 757-140/1306

EPA-600/2-78-033
June 1978

SEPARATION OF ALGAL CELLS FROM WASTEWATER LAGOON EFFLUENTS

Volume I:

Intermittent Sand Filtration to Upgrade Waste Stabilization Lagoon Effluent

by

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. The complexity of the environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

As part of these activities, this report was prepared to make available to the sanitary engineering community a full year of operating and performance data from a field scale intermittent sand filter system employed to upgrade waste stabilization lagoon effluent. The main objective of this research was to determine whether or not algae could be removed from the lagoon effluent by this method in an economical manner that would not require a great amount of operator time.

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

ABSTRACT

A project to evaluate the performance characteristics of the intermittent sand filter for polishing lagoon effluents was conducted. Techniques described in the literature for summer and winter operation were applied to determine if filter effluents would consistently meet PL 92-500 requirements.

It was found that effluent quality is affected by temperature and hydraulic loading rate variations, but that effluents meet very stringent water quality standards. Effluent values of less than 10 mg/l BOD_5, 10 mg/l SS and 5 mg/l VSS were consistently met. Organic nitrogen conversion and excellent nitrification were also found to take place within the filters.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

BOD_5 -- five day Biochemical Oxygen Demand
c -- similarity index
$\bar{c}$ -- average number of organisms in a taxonomic group
cfs -- cubic feet per second
cm -- centimeters
cm/sec -- centimeter per second
COD -- Chemical Oxygen Demand
CO_2 -- carbon dioxide
CO_3^- -- carbonate ion
CH_4 -- methane
DO -- dissolved oxygen
e -- effective size
F -- frequency of a given taxonomic group
FeS -- ferrous sulfide
ft -- feet
fps -- feet per second
gal -- gallon
gpm -- gallon per minute
hr -- hour
i -- index number identification
in -- inches
j -- index number identification
kg -- kilogram
lbs -- pounds
ln -- natural logarithm
m -- meter
m^2 -- square meters
m^3/ha.d -- cubic meters per hectare-day
MGAD -- million gallons per acre per day
mg/l -- milligram per liter
ml -- milliliter
mm -- millimeter
mm^3 -- cubic millimeters
N_2 -- nitrogen gas
N_2O -- nitric oxide
NH_3 -- ammonia
NH_3-N -- ammonia-nitrogen
NO_3^- -- nitrate ion
NO_2-N -- nitrite nitrogen
NO_3-N -- nitrate nitrogen

$O\text{-}PO_4\text{-}P$ -- orthophosphate phosphorus
P -- prominence value
PO_4 -- phosphate ion
$SO_4^=$ -- sulfate ion
SS -- suspended solids
temp. -- temperature
Total P -- total phosphorus
U -- uniformity coefficient
VSS -- volatile suspended solids
X -- pounds of suspended solids removed per acre of filter surface per day
Y -- length of filter run

SYMBOLS

°C -- degrees centigrade
°F -- degrees fahrenheit
μ -- micron
Σ -- summation
% -- percent
$ -- United States dollars

ACKNOWLEDGMENTS

The cooperation and assistance of the Logan City Engineer, Mr. Ray Hugie, is greatly appreciated. Assistance in the operation of the Logan City Waste Stabilization Lagoon System was provided by Logan City personnel.

SECTION 1

INTRODUCTION

NATURE OF THE PROBLEM

Most cities and communities in the United States recognized their responsibility toward protecting the environment before the Federal Water Pollution Control Act (PL 92-500) was passed in 1972. Those accepting this responsibility had acted to decrease their negative influence on nature through various individualized domestic waste treatment schemes. Larger cities required compact plants to minimize land usage and had the resources to employ expert operators to run those plants. Small communities, as well as many industries had done just the opposite to meet their needs. They utilized the relatively inexpensive land available to them for a lagoon-type treatment system which demanded little maintenance and almost no operator expertise. The performance of lagoon systems and the advantages they offered to small treatment operations made them one of the most commonly used primary and secondary waste treatment systems in the U.S. According to Caldwell, Parker and Uhte (1973) 34.7 percent of the 9,951 secondary treatment systems in this country in 1968 were stabilization ponds. Of these 3,453 ponds, 90 percent served communities with 10,000 people or less.

The passage of PL 92-500 with its stringent effluent standards and rigid time table has made it necessary to upgrade virtually every treatment system in the United States, but it has not changed the limiting conditions which encouraged the development of these systems in the first place. Large cities must still use technically advanced schemes to treat their wastes, while small communities must utilize available land--both need to be able to improve their present system rather than bear the costs of a completely new system.

Editorial Note

The definition of secondary treatment for federal regulation of municipal wastewater treatment plant effluents has been or is being modified. The Federal Register Vol. 41, No. 144, Monday, July 26, 1976, pp. 30786-30789, contains amendments pertaining to effluent values for pH and deletion of fecal coliform bacteria limitations from the definition of secondary treatment. The Federal Register Vol. 41, No. 172, Thursday, September 2, 1976, contains proposed changes in the suspended solids requirements for small municipal lagoon systems serving as the sole process for secondary treatment of wastewaters.

One proposed technique to enhance stabilization pond effluents is intermittent sand filtration. This is essentially an add-on operation to existing lagoon systems and complements the advantages of these systems, i.e., available and relatively inexpensive land, low operation costs and the utilization of present municipal employees. Initial studies using bench and pilot scale filters were very encouraging. This study was undertaken as a continuation of Marshall and Middlebrooks' (1974) work on intermittent sand filters.

OBJECTIVES

The objectives of this study were:

1. To investigate on a prototype scale the feasibility of using the intermittent sand filter as a polishing unit for stabilization ponds.

2. To establish operating parameters for the intermittent sand filter using stabilization pond effluents.

3. To develop winter operation techniques.

4. To project capital, operating and maintenance costs from the prototype filters.

5. To answer the following performance questions:

   a. Will stringent effluent quality standards be consistently met?
   b. Will filter loading rates effect effluent quality?
   c. Can filter plugging be predicted?
   d. Will deep penetration eventually necessitate sand replacement?
   e. Will filter run lengths become shorter over time?
   f. For a given filter run, is there a period of maximum removal efficiency?
   g. Will an ice cover affect performance and/or operation?
   h. Will removal efficiency increase or decrease from one filter run to another?

SCOPE

This project examined the performance characteristics of six prototype intermittent sand filters over a one year period. Lagoon effluents were applied to the filters at varying hydraulic loading rates on a daily basis to determine the polishing capabilities of the filters. Filter performance was then evaluated in the context of practical application to existing lagoon facilities and effluent quality.

The project also examined operational techniques. Several methods of summer and winter operation were evaluated in order to eliminate those that produced poor effluent quality or resulted in filter problems.

A general cost analysis was performed on the basis of experience gained from the project.

SECTION 2

CONCLUSIONS

The following conclusions concerning the operation and performance of intermittent sand filters employing a 0.17 mm effective size filter sand to upgrade waste stabilization lagoon effluent are based on the results of this twelve month study.

1. Intermittent sand filters with a 0.17 mm effective size filter sand will consistently produce an effluent with a five day biochemical oxygen demand (BOD_5) of less than 10 mg/l, and a chemical oxygen demand (COD) of less than 25 mg/l.

2. Intermittent sand filters with a 0.17 mm effective size filter sand will consistently produce an effluent with a suspended solids (SS) concentration of less than 10 mg/l and a volatile suspended solids concentration (VSS) of less than 5 mg/l.

3. Intermittent sand filters do not significantly reduce the total phosphorus or orthophosphate concentrations of lagoon effluent.

4. Nitrification is a significant process within intermittent sand filters. Ammonia-nitrogen is almost totally converted to nitrate-nitrogen. Intermittent sand filter effluent ammonia-nitrogen concentrations were consistently less than 0.6 mg/l.

5. Intermittent sand filters will consistently produce an effluent nitrite-nitrogen concentration less than 0.10 mg/l.

6. Intermittent sand filters will produce a highly nitrified effluent. The effluent nitrate-nitrogen concentrations for this study were consistently greater than 4 mg/l.

7. Intermittent sand filters will consistently produce an effluent with a pH of from 7.1 to 8.5 and, in general, tend to buffer the lagoon effluent pH.

8. Intermittent sand filters have little effect on the lagoon effluent temperature.

9. Intermittent sand filters tend to reduce the dissolved oxygen (DO) concentration of lagoon effluents super-saturated with dissolved oxygen and increase the dissolved oxygen (DO) concentration of lagoon effluents which are low in dissolved oxygen concentration.

10. All algal genera encountered during this study were effectively removed by intermittent sand filters with a 0.17 mm effective size filter sand.

11. Intermittent sand filter run lengths appear to be related to the algal genera being filtered, hydraulic loading rate, influent suspended solids, and temperature.

12. Intermittent sand filter run lengths in this study may be described by the regression equation: $Y = 5240\ X - 1.204$, where Y = length of filter run in days and X = pounds of suspended solids (SS) removed per acre of filter surface per day. However, this equation did not adequately describe filter run lengths achieved in previous studies.

13. Intermittent sand filter effluent quality was not significantly affected by various hydraulic loading rates between 1871 to 9354 m^3/ha.d (0.2 MGAD to 1.0 MGAD).

14. To achieve a high effluent quality, maximum total mass of pollutants removed, and a practical filter run length, intermittent sand filter hydraulic loading rates should range from 3742 to 5613 m^3/ha.d (0.4 to 0.6 MGAD).

15. Aerobic conditions within the intermittent sand filter bed are essential for optimum operation and performance.

16. Anaerobic conditions within an intermittent sand filter bed will significantly reduce the effluent quality and length of filter run.

17. In general, intermittent sand filter effluent quality does not change significantly within a specific filter run period.

18. Winter operation of intermittent sand filters did not create any serious operational problem, however, a ''ridge and furrow'' or ''staked'' technique should be employed.

19. Continuous flooding to maintain standing water at all times on the intermittent sand filter bed surface will create anaerobic conditions within the intermittent sand filter bed and significantly reduce effluent quality.

20. Algal growth within the water standing above the intermittent sand filter surface can be significant and may substantially reduce filter run length.

21. Intermittent sand filter (0.17 mm effective size filter sand) effluent quality is independent of effluent quality.

SECTION 3

RECOMMENDATIONS

The following recommendations concerning the operation and performance of intermittent sand filters to upgrade waste stabilization lagoon effluent are based on the results of this study.

1. Investigate the operation and performance of intermittent sand filters under various climatic and geographical conditions.

2. Investigate the effect of various effective size filter sands on intermittent sand filter effluent quality.

3. Determine the operation and performance of operating intermittent sand filters with different effective size filter sands in series.

4. Develop efficient methods of cleaning intermittent sand filters.

5. Determine the optimum period between filter loadings.

6. Determine the feasibility of upgrading trickling filter, activated sludge, on aerated lagoon effluents with intermittent sand filters.

7. Determine the ability of intermittent sand filters to remove bacteria, viruses, and carcinogenic compounds.

SECTION 4

REVIEW OF LITERATURE

STUDY BACKGROUND

The concept and practice of using intermittent sand filters for wastewater treatment is not new, but applying them to filtering algae from stabilization ponds is just beginning to receive attention. Originally intermittent sand filters were used for treating raw wastewaters. They probably developed through the marriage of two ideas; sewage farming which had been practiced for centuries (Daniels, 1945) and slow sand filters which were used to upgrade drinking water. But it was found that raw wastewater treatment was not practical because the low rate of application (93 m^3/ha.d or 0.01 MGAD) required extensive land area. This problem was partially offset by using intermittent filters as a secondary or tertiary process. Fair, Geyer and Okun (1968) state that settled urban wastewater and biologically treated effluents were upgraded by intermittent sand filtration. Metcalf and Eddy (1935) report that the process has been applied to upgrade sewage settled from plain sedimentation tanks and Imhoff Tanks as well as oxidized sewage from contact beds, trickling filters and activated sludge processes.

It has been recognized for some time that, ‘‘intermittent sand filters, when used for treating domestic sewage, will produce effluents of the highest degree of treatment now known’’ (ASCE - WPCF, 1959). Developments since 1959 may have superseded this endorsement, but intermittent filters still remain highly effective. They declined in use because new processes were discovered which were cheaper to operate and did not require extensive land areas.

Two things have revived interest in and possible need for intermittent sand filters. First, was the rapid growth experienced in Florida before and after World War II. According to Furman, Calaway and Grantham (1955) many motels, trailer parks, drive-in theaters, housing developments and consolidated schools sprang up in isolated locations throughout Flordia. A study on intermittent sand filtration was undertaken at the University of Florida in 1944 to determine design possibilities to meet the need of effective waste treatment for these isolated locations. The second development has been the use of stabilization ponds for wastewater treatment in this country and the requirement to upgrade the effluents from these ponds. There were only 631 ponds in the U.S. in 1957 (ASCE - WPCF, 1959). The number of ponds expanded to more than 3,400 in 1968 (Caldwell, Parker and Uhte, 1973). Intermittent sand filtration is one complementary process for lagoon systems.

There have been several different techniques developed to upgrade lagoon effluents. Caldwell, Parker and Uhte (1973) have included lowering aerial biochemical oxygen demand (BOD_5) loading, increasing detention time, recirculating pond effluents, changing the pond configuration, changing feed and withdrawal patterns, aerating the ponds and removing algae that grow in the ponds as possible methods for upgrading lagoon effluents. A well run pond system has great potential for meeting the most stringent effluent standards through algae removal. Because of this fact many studies have been undertaken to perfect a process that will best remove algae from pond effluents. One such study is reported by McGhee and Patterson (1974) in which upflow rapid sand filtration is used for algae cell removal. The process filters at a rate of 1.58×10^6 m^3/ha.d (169 MGAD) and achieves a 16.4 percent removal of BOD_5, a 17.9 percent removal of chemical oxygen demand (COD) and a 59.6 percent removal of suspended solids (SS). Other processes for removal include algae sedimentation by series pond configuration along with the periodic removal of bottom sludges to avoid nutrient recirculation, long detention times (250 days or more) to encourage crustacean growth which devour algae, removal by chemical coagulation and gravity separation followed by a rapid sand filter operation (Caldwell, Parker and Uhte, 1973), flow-through channels filled with water hyacinths, horizontal-flow rock filters, land application of the nutrient-rich waters and intermittent sand filtration. The last process incorporates many advantages of all the former options, i.e., competitive cost, ease of operation and a very high quality effluent (Marshall and Middlebrooks, 1974).

HISTORY OF INTERMITTENT SAND FILTRATION

A review of wastewater treatment by Imhoff, Muller and Thistlethwayte (1973) states that land or intermittent sand filtration was originally de vised in England by Sir Edward Frankland in 1868. It possibly evolved from the concept of slow sand filtration which had been described as early as 1828 (Daniels, 1945). Many of the same design parameters and operation procedures were used in both processes. As practiced in England in the early 1870's, raw wastewater was applied to a tract of land at a hydraulic loading rate of 5612 m^3/ha.d (0.6 MGAD) (Pincince and McKee, 1968). The area was first prepared by scraping off the top soil until sandy soil was reached and then applying the raw sewage (Imhoff, Muller and Thistlethwayte, 1973). Changes over time made intermittent sand filtration more like slow sand filtration in construction and operation. It was found that settled sewage achieved better results than raw sewage and that intermittently dosing the filters provided for longer filter runs.

Treating domestic wastes using intermittent sand filtration was first practiced in the United States at the Lawrence Experiment Station (Massachusetts) in 1887. Studies were undertaken there to find the best design and operational parameters to allow for the physical and biological processing of wastes (Pincince and McKee, 1968). The success of these experiments and the high quality of water that the filters produced encouraged their construction in this country. The first filters to be put into community use were at Farmington, Massachusetts in 1889 and by 1903 there were 23 systems operating in Massachusetts alone (ASCE - WPCF, 1959).

In 1945 there were 448 filters operating in this country. This number decreased to 398 by 1957 (ASCE - WPCF, 1959) because growing population centers required more wastewater treatment. The lack of land area needed for filtering this water inevitably caused the decline of the intermittent sand filter (Marshall and Middlebrooks, 1974). Other processes which achieved a lower quality, but satisfactory effluent were found which required much less land area. Two of these processes in particular, the contact bed and the trickling filter, were developed from intermittent sand filters (Imhoff, Muller and Thistlethwayte, 1973).

PREVIOUS INVESTIGATIONS

Studies at the University of Florida

It was noted earlier that the University of Florida at Gainesville studied intermittent sand filters as a means to provide wastewater treatment for sparcely populated and remote areas of the state (Calaway, 1957; Calaway, Carroll and Long, 1952; Furman, 1954; Furman, Calaway and Grantham, 1955). This process was chosen because of several advantages to small installations: no mechanical equipment, no skilled labor, small maintenance, low head loss, flying insects are no problem, high quality of effluent, no secondary sludge to handle and bacteria are effectively removed. They noted problems also: large land area needed, weather effects performance, requirement of a satisfactory sand, weeds grow on the beds, filters require scraping and removal of surface sand, and the beds must be quickly and completely covered (Calaway, 1957).

The filters used in the study were 2.3 x 2.3 meters (7.4 x 7.4 feet) with 46 - 76 centimeters (cm) (18 - 30 inches) of sand over a 15 cm (6 inch) gravel bottom. Sands tested had an effective size of 0.25 to 1.04 mm and a uniformity coefficient of 1.7 to 3.27. Hydraulic loading varied from 935 - 5613 m^3/ha.d (0.1 - 0.6 MGAD). Pretreatment of the domestic sewage included a 1.9 cm (3/4 in.) bar screen, sedimentation or Imhoff tank retention for two hours, a holding tank and then filtration (Furman, Calaway and Grantham, 1955). Each sand, bed depth and loading rate was evaluated for single and multiple daily dosages for BOD_5 and SS removal and nitrification within the bed.

It was found that 89 percent of the BOD_5 removed was in the top 30 cm (12 inches) of sand because this is the zone of active biological activity (Calaway, Carroll and Long, 1952). This finding led to the conclusion that bed depths could go as low as 46 cm (18 inches) and still remain effective. In the tests, little difference was found between performance of the 46 cm (18 inch) and the 76 cm (30 inch) bed depths. They both achieved 96 to 99 percent BOD_5 removal, 88 - 93 percent SS removal and 63 to 90 percent nitrogen oxidation (for the 0.25 mm effective size, 2.22 uniformity coefficient sand) (Furman, Calaway and Grantham, 1955).

Further conclusions of the Florida studies were: better BOD_5 removal is achieved with two loadings a day rather than one loading per day, dosages beyond two a day do not increase removal efficiency, the smaller size sands give much better results, hydraulic and organic loading rates show little variation in BOD_5 removal performance, sand filters oxidize almost all of the adsorbed and mechanically removed nutrients, biological oxidation is the most important purifying action in the filters, and nitrification decreases with increased loading rates (Calaway, 1957; Furman, Calaway and Grantham, 1955). It was determined that a minimum bed depth of 46 - 61 cm (18 - 24 inches) with sand having an effective size of less than 0.44 mm and a uniformity coefficient less than 3 to 4 should be used. The filters should be loaded twice a day with settled sewage at a hydraulic loading rate of 1403 m^3/ha.d (0.15 MGAD) for best performance (Calaway, 1957; Furman, 1954). Using these design and operation parameters the intermittent sand filter would produce a very high quality effluent that would have a minimum impact on receiving waters.

Dune Sand Filtering of Algae

During the late 1960's experiments were undertaken in Israel to study the possibility of using domestic sewage stabilization pond effluents to recharge groundwater supplies (Folkman and Wachs, 1970). According to Folkman and Wachs (1970) these studies had shown that significant concentrations of algae had remained in the effluent after this water had passed through 3.5 meters (11.5 ft.) of dune sand, while experiments had been successful in using slow sand and rapid sand filters for algae removal. So a study was undertaken to follow algae transfer through dune sands.

The algae genus used in this experiment was Chlorella sp. which is the smallest (3 - 5 μ) found in the stabilization ponds of Israel. It was found that this species divide in darkness into daughter cells and with proper substrate they will remain viable for long periods of time with no light. Experiments showed that in darkness the numbers of cells increased from 8,000 to 10,000/mm^3 in a few hours. With this division the average size shifted from 4.2 μ to 3.5 μ and the range of size distribution became narrower. This finding implies that filters may remove this algae initially; but that the efficiency of removal decreases through the filter as more, smaller and a narrower size distribution of cells must be removed (Folkman and Wachs, 1970).

The experiment showed that the retention of algae occurred mostly in the upper sections of the sand column (top 5 cm or 2 inches), which corresponded to the area of incremental head loss. Removal was constant, but much lower, through the rest of the column where there was a fairly constant hydraulic gradient. The experiment also showed that algae concentrations as a function of depth closely followed the filtration equation proposed by Ives (1961).

Other conclusions were made from this study. One important consideration is the sand used for filtration. The dune sand used in Israel was of marine origin which contained a lot of calcium carbonate. As respiration took place within the filter the carbon dioxide (CO_2) given off transformed the calcium into soluble bicarbonate. As a result the sand itself changed in size distribution as well as increasing the hardness of the percolating water (Folkman and Wachs, 1970). Filter efficiency as well as quantity of water filtered was improved by lowering the velocities used in filtration during this experiment.

Findings at Utah State University

Marshall and Middlebrooks (1974) undertook a two phase study during 1972-73 to determine if intermittent sand filtration could effectively upgrade stabilization pond effluents in the State of Utah to meet the State's Class ''C'' water quality standards ($BOD_5 \leq 5$ mg/l, pH = 6.5 - 8.5, total coliform $\leq$ 5,000/100 ml, fecal coliform $\leq$ 2,000/100 ml and dissolved oxygen (DO) $>$ 5.5 mg/l). Phase I was a laboratory experiment using bench scale filters to evaluate the process while phase II dealt with pilot scale filters in the field. Both phases studied the variables of hydraulic loading rate, effective size of sand and algal concentration in relation to effluent quality (Harris et al., 1975).

Phase I was broken into three periods where controlled quantities of suspended solids were applied at concentrations of 15 mg/l, 30 mg/l and 45 mg/l and hydraulic loading rates of 935, 1871 and 2806 m^3/ha.d (0.1, 0.2 and 0.3 MGAD). The three effective sand sizes used were 0.17 mm, 0.35 mm and 0.72 mm. None of the filters plugged (had water remaining on the filter surface after a 24-hour period) during these runs of six weeks each.

The field study used nine pilot scale filters which were 1.2 meters (4 feet) square. They were filled with 0.17 mm, 0.74 mm and 0.6 cm gravel initially which was soon changed to six filters filled with the 0.17 mm size sand. Loading during the fall of 1972 matched that of period II in the laboratory phase. Loading was increased to 3742, 4677, 5613, 6548 and 8419 m^3/ha.d (0.4, 0.5, 0.6, 0.7 and 0.9 MGAD) for the 0.17 mm size sand and 3742, 4677, and 5613 m^3/ha.d (0.4, 0.5 and 0.6 MGAD) for the 0.74 mm size sand the next spring. No plugging occurred during these filter runs.

Results of these experiments showed that nitrogen applied in the influent was largely ammonia which readily oxidized to nitrate within the filters. Higher loading rates decreased the nitification process and the smaller effective size sands increased it. It was also found that BOD_5 removal decreased as the loading rate increased and decreased as the effective size of the sand increased. Lower temperatures also reduced BOD_5 removal efficiencies. BOD_5 removal did not increase as the ''schmutzdecke'' or organic surface mat built up over the filter run, but SS removal did increase over the run in the laboratory experiment. Hydraulic loading rate effects on SS removals in the field studies were inconclusive because of the large quantities of fines which continually washed from the filters. There was also no indication in the field runs that SS removal efficiency increased as the run progressed.

Volatile suspended solids (VSS) removal did indicate that efficiency decreased as hydraulic loading rate increased. The predominant algae species during the entire experiment was Chlamydomonas sp. which was never less than 70 percent of the algae present. It was found that the percent removal of algae cells increased as influent concentrations increased, but that more cells passed through the filters also. This removal efficiency seemed to increase as the filters aged, but did not increase as they became plugged. Coliform removal decreased as the effective size of sand increased.

It was concluded from the experiment that phosphorus removal was the result of ion exchange with the sand rather than growth needs within the filters. This conclusion was made because removal was higher near the first part of the experiment and the smaller sand, with its larger surface area, had higher removal of phosphorus.

The experiment showed that sand size did have an effect on the quality of the effluent produced by filtration and that size was related to the time of operation before plugging occurred. (The laboratory experiments were carried beyond the six week runs lengths to see when this would happen.) The 0.17 mm effective size sand filters were found to operate approximately 100 days at hydraulic loading rates of 3742 to 5613 m^3/ha.d (0.4 to 0.6 MGAD) before cleaning was required. This was with an influent SS concentration averaging 20 mg/l. At loading rates of 6548 to 7484 m^3/ha.d (0.7 to 0.8 MGAD) and an influent average concentration of 42 mg/l SS, this same sand was found to operate for 32 consecutive days before plugging (Marshall and Middlebrooks, 1974).

It was concluded that ''if operated and loaded properly, all existing wastewater treatment plants in the State of Utah could be upgraded by intermittent sand filteration to meet Class 'C' state standards'' (Marshall and Middlebrooks, 1974).

INTERMITTENT FILTER THEORY

Filtering Mechanisms

As wastewater passes through an intermittent sand filter several mechanisms act to filter out and chemically change both suspended solids and dissolved materials found in the wastewater. Metcalf and Eddy (1935) state that there are two filtering actions taking place: 1) the physical removal of suspended matter by straining, adsorption and sedimentation on the downstream side of the sand grain and 2) the biochemical removal of colloidal and dissolved organic substances which are transformed into stable materials. A third may be added to this, that of purely chemical precipitation or dissolution caused by aeration coming into or moving through the filter and chemical reactions with the sand itself. This later mechamism will play a minor part if the sand that is used is free from calcareous and argilaceous matter (Anonymous, 1910).

It has been found that filtration takes place in the top 5 - 6 cm (2 - 2 1/2 inches) of an unstratified filter (Borchardt and O'Melia, 1961; Fair, Geyer and Okun, 1968; Folkman and Wachs, 1970; Ives, 1961). This is probably due to three reasons. One is the fact that larger particles are strained out by the sand surface. Biological growth develops here and as more particles are trapped on the surface the pore passage becomes even smaller. A biological mat or ''schmutzdecke'' is formed on the filter surface which acts as a more effective straining device than the sand itself. The second reason is the fact that the top few centimeters of an intermittent sand filter is the most active area biologically because oxygen is most available here. Bacteria form a gelatinous film over each sand grain in this aerobic zone. These bacteria feed on and break down the complex organic materials adsorbed from the sewage (Metcalf and Eddy, 1935). A third reason is, that due to the hydraulics of the filter, the velocity head is greatest in the top few centimeters. In order for suspended particles to be adsorbed on the sand grains they must be removed from the stream lines of the fluid. At high velocities, momentum and gravity cause particles to cross stream lines, impact on sand grains and be adsorbed (Ives, 1961) by electrostatic and van der Waal's forces.

In their study on algae removal in Israel, Folkman and Wachs (1970) found that particles adsorb to sand grains by opposite electrical charges and that sand with ferric and aluminum ions is especially efficient for algal and bacterial filtration. Their study confirmed the findings of Ives (1961) who had worked with radiactive *Chlorella* and *Scenedesmus* to develop filtration equations for algal removal. He had found that head loss was approximately constant below the surface removal depth and that some algae penetrated the entire bed (Ives, 1961).

A report by Pincince and McKee (1968) described the biochemical processes that are active within an intermittent sand filter. They state that pollutants are removed from the percolate by physical adsorption, some diffusion, biological assimilation and biosynthesis. These processes remove dissolved, colloidal and suspended substances while returning dissolved minerals and stabilized organics. Aerobic conditions will produce water (H_2O), carbon dioxide (CO_2), carbonate ion (CO_3^-), sulfate ion ($SO_4^=$), phosphate ion ($PO_4^=$) and nitrate ion (NO_3^-) while anaerobic conditions produce carbon dioxide (CO_2), methane (CH_4) and ammonia (NH_3). Denitrification occurs in the anaerobic portions of the filter. This may be assimilatory where the nitrogen is reduced to negative three valance and incorporated into cells or dissimilatory which causes the production of nitrogen gas (N_2), nitrous oxide (N_2O) and nitric oxide (NO) gases and loss of nitrogen from the system. Sulfates are reduced under anaerobic conditions with the resultant presence of black ferrous sulfide (FeS). Some stabilization of organics occurs because of bacterial fermentation in the bottom layers of the filter also.

Nitrification is an active process within the aerobic zones of the filter which increase in depth as oxygen moves into the deeper layers following wastewater applications. According to Pincince and McKee (1968) nitrification occurs down to the top of the capillary fringe in the filter.

They also found that bacterial activity is limited during the time of water ponding because of a lack of oxygen. The study showed that aerobic activity decreases more than an order of magnitude from 0 to 40 cm depths while activity is constant from 40 to 70 cm depths (Pincince and McKee, 1968). This further supports the fact that most of the stabilizing processes and filtering action is taking place in the upper layers of an intermittent sand filter.

Biota in Filters

Some of the most complete studies on the biota present in intermittent sand filters were made at the University of Florida (Calaway, 1957; Calaway, Carroll and Long, 1952). It was recognized that the purification mechanism was biological as well as physical. The studies showed that there were many genera and species of aerobic heterotrophic bacteria at different levels of the filter (Calaway, Carroll and Long, 1952). The predominant species which accounted for most of the stabilization of the wastewater were *Zooglea ramigera*, *Flavobacterium*, *Bacillus*, *Alcaligenes faecalis*, *Nocardia* and *Streptomyces* (Calaway, 1957; McCabe and Eckenfelder, 1956). The last two species utilize humus within the filter which would otherwise cause clogging. Another study by Laak (1970) found that coliforms, fecal coli, *Pseudomonas* and *Proteus* species were present also. Most coliforms are found in the top 15 cm (6 inches) of the filter. All but the fecal streptococci are removed very efficiently by intermittent sand filtration (Calaway, Carroll and Long, 1952). *Nitrosomonas* and *Nitrobacter* are other species found in the upper filter layers. All bacterial species in the system decrease with depth, but not at the same rate.

According to Calaway, Carroll and Long (1952) Zooglea ramigera require highly aerobic conditions to grow and survive. They also require large amounts of food for viable populations, which may not be available in the deeper layers of sand. It was found that this species resides only in the top 30 cm (12 inches) of sand where 89 percent of the BOD_5 removal occurs (Furman, Calaway and Grantham, 1955).

Protozoa present in the filters included Colpoda and Paramecium, two ciliates, and Peranema, a flagellate (Calaway, 1957). Amoeba were also present in abundance (Calaway, 1957; McCabe and Eckenfelder, 1956). No protozoa were found below 30 cm (12 inches) since they feed on the bacteria in the filter (Calaway, Carroll and Long, 1952).

The metazoa found in the filters consume bacteria and feed on bed slimes which keep the filters aerated (Calaway, 1957). Oligochaet worms also consume slimes and sludges and play an important part in keeping the filter bed open and active.

Filter Clogging

There have been many theories proposed to explain the clogging action within sand and soil systems used for wastewater treatment. All of them, however, agree that the major clogging action occurs in the top 2 - 5 cm (1 - 2 inches) of the filter. Early reports observed that intermittent sand filters were rejuvenated by removing this top layer of sand (Fuller, 1908; Saville, 1924) or by simply scarifying the surface layer by raking (Saville, 1924; Story, 1909). These early authors realized that the formation of the ''schmutzdecke'' was at least a factor in the plugging mechanism. Asterionella was identified by Story (1909) as causing sand caking in filters at Springfield, Massachusetts. Gaub (1915) stated that filter beds can become inefficient by rough treatment of the sand surface which causes deep penetration of organic matter and filth into the bed. Much later, Pincince and McKee (1968) noted that bacterial growth causes plugging by increasing the moisture retention within the filter. This decreases gas diffusivity because the porosity is decreased. This thought was supported by Iwasaki (1937) who observed that bacterial growth on sand filters in Tokyo effects the impediment modulus or filterability of the sand bed.

Studies by McGauhey (1968) led him to conclude that there were three important clogging actions within sand and soil systems. The first is physical clogging which is caused by: 1) compaction of the soil by superimposed loads such as water and equipment, 2) migration downward of fines during construction, 3) migration of fines due to rainfall beating against the surface and 4) the washdown of fines. The second action is chemical clogging caused by ion exchange with the sand. This is not a problem in non-calcarious or argilaceous sands. The third and largest factor is biological clogging which is a surface phenomenon caused by the organic development of the ''schmutzdecke.'' As long as air can get to the filter surface (the reason for loading intermittently) high-rate aerobic decomposition will keep this mat porous. Allowing the mat to dry and crack also increases infiltrative capacity. Once this system becomes anaerobic, however, the decomposition rate slows and the filter clogs rapidly because of slime growth and the deposition of ferrous sulfide--a black particulate matter. This zone of clogging will be very shallow if the loading is stopped when plugging occurs. The ferrous sulfide will oxidize to a soluble sulfate in a short time upon resting and draining the system. Metcalf and Eddy (1935) also state that the bottom drains can become plugged by sand and organic growth to cause problems in the filter.

Studies by deVries (1972) generally support the above explanation as he also observed that filter failure was the result of pore clogging. This was caused by the sludge layer or organic mat on the surface of the sand sealing off the filter pores. When this occurred, degradation ceased and the filter was soon plugged. deVries noted a dark-grey area which extended 8 cm into the sand (which was probably the ferrous sulfide that McGauhey spoke of); but states that pore clogging took place on the surface of the sand, not in this dark layer. He also states that the system recovered in about 8 days when allowed to rest at room temperature. The organic matter on the filter surface dried and oxidized during this time.

A laboratory experiment by Jones and Taylor (1965) loaded primary settled sewage on filters with 25 cm (10 inches) of sand over 25 cm (10 inches) of gravel. They found that clogging occurred at the sand/gravel interface, as this was the area of organic and inorganic deposition in their filters. No other study reports this phenomenon.

The theory of clogging has been taken at least one step further by the studies of Avnimelech and Nevo (1964), Laak (1970), Mitchell and Nevo (1964) and Thomas, Schwartz and Bendixen (1966). All of these studies assert that clogging occurs in the top 1 - 2 cm most intently and that clogging is caused by a decrease in soil permeability due to microbial action. It is not caused by build-up of ferrous sulfide which is only an indicator of anaerobic conditions within the filter. All of these reports point out that bacterial cells, along with polyuronide and polysaccharide concentration increases, eventually clog the filter. They do not agree as to the extent that each of these elements play in this plugging action, though.

The process of clogging occurs in three distinct periods (Jones and Taylor, 1965; Thomas, Schwartz and Bendixen, 1966). The longest period is at the first of the run where the infiltration rate is gradually reduced. This reduction is proportional to the effluent percolated through the filter and probably due to an accumulation of organic deposits on the surface. The second period is very short or non-existent. There a quasi-equibibrium state may exist in which the organics are degraded at the rate of application. The third period is characterized by anaerobic conditions and a rapid decrease in the rate of infiltration. Under these conditions a filter will clog from 3 - 10 times faster than under aerobic conditions (Jones and Taylor, 1965). Thomas, Schwartz and Bendixen (1966) do not include the second period above; but replace it by the period in which the infiltrative rate is sharply reduced. Their third period is a continuation of anaerobic conditions where an asymptotic lowering of the infiltration rate occurs.

DESIGN PARAMETERS

The design of intermittent sand filters is comparable to that of slow sand filters.* Major differences between the two systems lie in their modes of operation. General similarities and differences between slow, rapid and intermittent sand filters are listed in Table 1. The portions of the table for slow and rapid sand filters were taken from Fair, Geyer and Okun (1968) while the parameters for intermittent sand filters are the result of evaluating and summarizing more than 20 separate sources. An explanation of some of these parameters may prove helpful in making correct design decisions.

Before the acreage needed for intermittent sand filtration can be calculated a hydraulic loading rate must be decided upon. This is a function of many things including climate, suspended solids, BOD_5 loading, length of filter runs desired, sand size and uniformity coefficient. An effective size sand of 0.3 - 0.6 mm with a uniformity coefficient of less than 3.5 may run continuously at a hydraulic loading rate of 402 m^3/ha.d (0.043 MGAD) because of continuous biological stabilization (Salvato, 1955). Settled urban wastewaters may be loaded at 374 - 1123 m^3/ha.d (0.04 - 0.12 MGAD) and biologically treated effluents at 3742 - 7484 m^3/ha.d (0.4 - 0.8 MGAD) according to Fair, Geyer and Okun (1968). Higher loading rates at constant BOD_5 concentrations will cause shorter filter runs before plugging. Any size operation should have 3 - 4 beds (ASCE - WPCF, 1959; Anonymous, 1910) to allow for cleaning and resting of the filters.

Filter construction may be the same as that used in stabilization pond construction, but with the bottom contoured for effective drainage. One author suggested that concrete walls be used to divide the beds rather than soil banks (Anonymous, 1910). Filters may have to be raised in order for the underdrains to flow completely free also. It is important that the underdrains have a free outlet so that the filter can be ventilated from below (Babbitt and Baumann, 1958) and the capillary action of the sand will be minimized (ASCE - WPCF, 1959; Babbitt and Baumann, 1958; Daniels, 1945; McGauhey, 1968).

Underdrains should be a minimum of 10 cm (4 inches), placed at a maximum of 9.1 meters (30 feet) apart (Imhoff, Muller and Thistlethwayte, 1973). A more ideal system will have 15 - 20 cm (6 - 8 inch) underdrains placed 3 - 3.5 m (10 - 12 feet) apart for complete and quick drainage (ASCE - WPCF, 1959; Anonymous, 1910; Babbitt and Baumann, 1958; Furman, Calaway and Grantham, 1955; Holmes, 1945; Metcalf and Eddy, 1935; Story, 1909). If open joint underdrains are used, there should be a 2 cm (3/4 inch) opening every 60 cm (2 feet) (Story, 1909). Underdrain slopes of 1/2 percent (Metcalf and Eddy, 1935) or enough to achieve a 0.9 - 1.2 meter per sec (3 - 4 fps) velocity are desirable (Babbitt and Baumann, 1958).

Gravel should be placed around and over the underdrains to a minimum of 30 cm (12 inches) (ASCE - WPCF, 1959; Anonymous, 1910; Babbitt and Baumann, 1958;

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*References Gregory (1914), Karalekas (1952), Mitchell (1921), Powell (1911), and Saville (1924) deal exclusively with slow sand filters. They are included in the design section as a supplement to the information found on intermittent sand filters.

TABLE 1. GENERAL CONSTRUCTION AND OPERATION FEATURES OF CONVENTIONAL SLOW, RAPID, AND INTERMITTENT SAND FILTERS (FAIR, GEYER, AND OKUN, 1968)

	Slow Sand Filters	Rapid Sand Filters	Intermittent Sand Filters
Rate of filtration	1 to 3 to 10 MGAD	100 to 125 to 300 MGAD	0.2 to 0.6 to 1.2 MGAD
Size of bed	Large 1/2 acre	Small 1/100 to 1/10 acre	Large, 1/2 acre
Depth of bed	12 in. of gravel; 42 in. of sand, usually reduced to no less than 24 in. by scraping	18 in. of gravel; 30 in. of sand, or less; not reduced by washing	12 in. of graded gravel; 36 in. of sand, reduced to no less than 18 in. by scraping
Size of sand	Effective size 0.25 to 0.3 to 0.35 mm; coefficient of nonuniformity 2 to 2.5 to 3	0.45 mm and higher; coefficient of nonuniformity 1.5 and lower, depending on underdrainage system	Effective size 0.12 to 0.20 to 0.50 mm; uniformity coefficient 2 to 4 to 10
Grain size distribution of sand in filter	Unstratified	Stratified with smallest or lightest grains at top and coarsed or heaviest at bottom	Unstratified
Underdrainage system	Split tile laterals laid in coarse stone and discharging into tile or concrete main drains	(1) Perforated pipe laterals discharging into pipe mains; (2) porous plates above inlet box; (3) porous blocks with included channels	Perforated pipe or open joint laterals 8 to 12 to 30 ft. apart. Slope of 1/2 % or greater for 3-4 fps velocity. 6" drains with free outlet
Loss of head	0.2 ft initial to 4 ft final	1 ft initial to 8 or 9 ft final	0.2 ft initial to 4 ft final
Length of run between cleanings	20 to 30 to 60 days	12 to 24 to 72 hr	5 to 30 to 150 days--dependent upon loading rate and suspended solids concentration
Penetration of suspended matter	Superficial	Deep	Superficial--top 1 to 3 in.
Method of cleaning	(1) Scraping off surface layer of sand and washing and storing cleaned sand for periodic resanding of bed; (2) washing surface sand in place by washer traveling over sand bed	Dislodging and removing suspended matter by upward flow or backwashing, which fluidizes the bed. Possible use of water or air jets, or mechanical rakes to improve scour	(1) Scraping off surface layer of sand and washing and storing cleaned sand for periodic resanding of bed; (2) washing surface sand in place by washer traveling over sand bed
Amount of wash water used in cleaning sand	0.2 to 0.6% of water filtered	1 to 4 to 6% of water filtered	0.2 to 0.6% of water filtered. Return wash water to head of lagoon system
Preparatory treatment of water	Generally none	Coagulation, flocculation, and sedimentation	Primary or secondary treatment of wastewaters
Supplementary treatment of water	Chlorination	Chlorination	Chlorination if required
Cost of construction, U.S.A.	Relatively high	Relatively low	Competitive where sand and needed land area are available
Cost of operation	Relatively low where sand is cleaned in place	Relatively high	Intermediate operation and maintenance. Unskilled labor can be used
Depreciation cost	Relatively low	Relatively high	Relatively low--approximately same as lagoon system

125 MGAD = 2 gpm per sq ft = 16 ft per hr = 125 m per day.

1 Acre = 0.4047 hectares
1 MGAD = 9354 m^3/hectare-day
1 Inch = 2.54 cm
1 fps = 30.48 cm/sec
ft = 0.305 m

Gregory, 1914; Holmes, 1945; Metcalf and Eddy, 1935). This is graded gravel with 13 cm (5 inches) of 3.8 - 5 cm (1 1/2 - 2 inch) maximum diameter, 7.5 cm (3 inches) of 2.5 cm (1 inch) maximum diameter, 7.5 - 10 cm (3 - 4 inches) of 1.3 cm (1/2 inch) maximum diameter and then pea gravel (ASCE - WPCF, 1959).

Sand is then placed in the filter to a maximum depth of 1.2 meters (4 feet) to allow for aeration of the entire bed (Metcalf and Eddy, 1935). A clean, rounded sand should be used which is free from loam, clay, humus, calcareous and argilaceous matter (Anonymous, 1910; Babbitt and Baumann, 1958). The sand should not be stratified as it is placed in the filter. Effluent quality is dependent upon the effective size of the sand. Studies have shown that smaller size sands will achieve better removal efficiencies of BOD_5, SS and coliforms. The effective size may range from 0.2 to 0.5 mm (ASCE - WPCF, 1959; Anonymous, 1910; Babbitt and Baumann, 1958; Daniels, 1945; Furman, 1954; Grantham, Emerson and Henry, 1949; Gregory, 1914; Holmes, 1945; Imhoff, Muller and Thistlethwayte, 1973; Karalekas, 1952; Metcalf and Eddy, 1935; Mitchell, 1921; Powell, 1911; Salvato, 1955). McGauhey (1968) has observed that a large uniformity coefficient may allow soil particles to be arranged in a way to make the soil mantle almost water-tight. Although this parameter has little effect on effluent quality it does have an effect on run lengths (Salvato, 1955). The uniformity coefficient may range from 1 - 10, but should be less than 4 if possible (ASCE - WPCF, 1959; Anonymous, 1910; Babbitt and Baumann, 1958; Gregory, 1914; Holmes, 1945; Imhoff, Muller and Thisthethwayte, 1973; Karalekas, 1952; Metcalf and Eddy, 1935; Mitchell, 1921; Powell, 1911; Salvato, 1955; Saville, 1924).

Filters must be dosed quickly and evenly for the entire bed area to be properly utilized (Anonymous, 1910; McGauhey, 1968; Metcalf and Eddy, 1935). If one portion of a bed is filtering more water than another because of inadequate dosing rates or an uneven bed, ''creeping failure'' will set in which produces a poor effluent, reduces the effective filtering area and causes severe recovery problems after plugging (McGauhey, 1968). It is recommended that no more than 232 m^2 (2500 ft^2) be supplied by each discharge point in a filter to assure adequate coverage (Anonymous, 1910). For quick and even distribution the flow rate should be 0.028 m^3/sec (1 cfs) for every 465 m^2 (5000 ft^2) of filter area (Metcalf and Eddy, 1935).

In designing the shape of the intermittent sand filter, two operating parameters must be taken into consideration. The first is that of cleaning the sand surface. There are basically three options to clean an intermittent sand filter: 1) to scrape off the top 2.5 - 5 cm (1 - 2 inches) of sand with shovels and transport it from the filter in wheelbarrows, 2) to transport the upper layer from the filter using a hydraulic ejector, and 3) to clean it in place using a wash machine. A wash machine operation will require tracks to run on; and long, narrow filters have been designed to utilize this method of cleaning (Anonymous, 1918). The second operating parameter to consider is that of water distribution onto the filter. The high velocities needed in distributing the water can cause sand scouring problems. Troughs have historically been used for water distribution without too much scouring, but not without problems. The problems include high trough maintenance, uneven settling of the troughs which cause poor distribution, some sand scouring around the trough and hampering of sand cleaning operations (ASCE - WPCF, 1959). Another method of distribution requires headwall construction at the point of discharge with paved areas or field stones around this to prevent scouring and erosion. This method can distribute water from the corners on a square bed, the end- or quarter-points on a long bed (Metcalf and Eddy, 1935), around the periphery on a large bed (Anonymous, 1910), or from a center discharge point using upflow pipes (ASCE - WPCF, 1959; Story, 1909). Two other possible methods of distribution include flow distributors like those used in trickling filters or a pipe system supported by concrete columns like those used on some contact beds.

FILTER OPERATION

General

Intermittent sand filters are simple and effective systems to operate, but common sense must be applied in making them successful. Marshall and Middlebrooks (1974) vividly illustrated the possibility of continuous filter operation in noting that one filter at the Lawrence Experiment Station had operated for 23 years without a need for removing sand from its surface. They calculated that this 2.02×10^{-3} hectare (0.005 acre) filter had processed 9069 m^3 (2,395,532 gallons) of wastewater containing 2722 kg (6,000 pounds) of organic matter. If an intermittent sand filter is permitted to drain freely and is kept aerobic by allowing adequate resting periods it will run indefinitely (deVries, 1972; McGauhey, 1968). And almost no maintenance will be needed because of its high organic decomposition and rapid nutrient oxidation rates.

It is difficult to balance the oxygen required to oxidize wastes and the quantity of oxygen added during the rest periods between the application of wastewater to intermittent sand filters (deVries, 1972; Fair, Geyer and Okun, 1968). When a severe imbalance occurs, anaerobic conditions develop and produce growths which clog the filter. But there are operation techniques which maintain aerobic conditions in the filter.

One of the most important operational techniques is to dose the filter rapidly to insure a uniform distribution of the wastewater so that the entire filter area is used (ASCE - WPCF, 1959; Anonymous, 1910; Daniels, 1945; Imhoff, Muller and Thistlethwayte, 1973; McCabe and Eckenfelder, 1956; McGauhey, 1968). Rapid dosing requires having a pump of adequate size (Anonymous, 1910). Most filters in 1959 were fed by an automatic air-lock siphon arrangement which required a large head to insure an adequate flow rate (ASCE - WPCF, 1959).

Keeping the filter bed smooth and level (Anonymous, 1910) and free from weeds and vegetation (Daniels, 1945) are necessary for good performance. However, Mitchell and Nevo (1964) stated that their studies showed plugging was correlated to a low redox potential within the surface layer of a filter. Prevention of the formation of this reduced layer in the filter would stop clogging.

A technique to optimize performance is to split filter dosings. At least two studies (Furman, 1954; Grantham, Emerson and Henry, 1949) found that split dosing yields better SS and BOD_5 removal and more complete nitrification. Splitting the filter dosages into 2 - 4 times a day or dosing every other day or two out of three days may also allow the filter enough aeration in the surface layers to remain aerobic (Babbitt and Baumann, 1958). A well designed system will contain 3 - 4 filters in which a large number of loading patterns may achieve an optimum rest period for each filter.

Other suggestions are given in the literature for increasing filter run lengths and avoiding problems. Babbitt and Baumann (1958) state that a mat of organic matter will increase to about a 0.6 cm (0.25 inch) thickness over the filter run. Rather than having to scrape this mat and the underlying sand from the filter it may be possible to roll it up and remove it. A second suggestion for minimizing operation costs is to rake the filter as it plugs or starts to plug (Fair, Geyer and Okun, 1968; Pincince and McKee, 1968; Saville, 1924; Smith, 1945; Story, 1909).* The technique of scarifying the surface of the filter by raking it prolongs the length of time between scraping operations. The practice apparently increases water flow in the filter as well as oxygen penetration (Pincince and McKee, 1968). Story (1909) reported that scrapings became very heavy if the beds were not raked 1 - 2 times in between. Although raking the bed does not yield the length of run that scraping it does, costs favor this practice. Saville (1924) stated that a 0.20 hectare (0.5 acre) slow sand filter in Hartford, Connecticut required 11 men, 8 hours to scrape and wash. The same filter was raked in 2 hours by 3 men. These filters were raked 5 times between each sand washing. If a filter plugs after a heavy rain it may be completely rejuvenated by raking, which simply unstratifies the top centimeters of the sand (Story, 1909).

It has been noted that the biological processes in a filter will keep it from clogging if an adequate length of time is allowed between dosings. These same processes will unclog a plugged filter (McGauhey, 1968; Metcalf and Eddy, 1935). No scraping is needed if time may be allowed for a filter to recuperate naturally. The time required will vary from 1 - 2 weeks in a filter with minor problems to over 8 weeks in an abused filter (one which has not been loaded evenly or has been continually loaded after being plugged) (Metcalf and Eddy, 1935). Capital costs generally make this option impractical so scraping is needed.

Major filter problems will result if a bed is harrowed or plowed or clean sand is added before the top 2.5 - 5 cm (1 - 2 inches) of sand are scraped off (Babbitt and Baumann, 1958; Daniels, 1945; Metcalf and Eddy, 1935; Story, 1909). Surface deposits are mixed into the lower layers by plowing a clogged bed. This reduces the filter's capacity. Placing new sand over old allows a thick, dirty layer to form on top of the old sand also (Story, 1909). Metcalf and Eddy (1935) caution that washing filter scrapings may wash away enough sand fines to change the uniformity coefficient. Penetration of suspended matter will increase through this sand, and a sealing surface may form under it when it's placed back on the filter. This problem was not noted in any of the papers which described washing machine operations or operations which replaced cleaned sand. However, there will definitely be no problem if the sand is removed and stockpiled until the filter depth is reduced to about 46 cm (18 inches). The remaining sand can then be removed, washed and the filter refilled to the original depth.

The three basic methods of sand cleaning were mentioned in the design section. Intermittent and slow sand filters were originally cleaned by hand. This was done by scraping or hoeing 2.5 - 5 cm (1 - 2 inches) from the filter surface and removing it from the filter in wheelbarrows (Story, 1909). The sand was then stored for future washing and use. Development of hydraulic ejectors made it possible to remove and replace the sand much more easily (Gaub, 1915; Saville, 1924; Smith, 1945) in slow sand filters. In this cleaning method the sand was scraped, piled and then transported by the hydraulic ejector out of the filter to be washed, stored and eventually replaced. Some operations washed the sand both coming and going to ensure a complete removal of organics (Saville, 1924). Another advancement over hand scraping and transporting was practiced on slow sand filters in Long Island. Two troughs were placed along each end of a filter at sand level. The water being filtered was allowed to drain to about 2 inches from the surface, then water was sent across the bed from one trough to the other. Men with rakes or stubble brooms broke up the ‘‘schmutzdecke,’’ and the suspended dirt was carried away with the water. This method used approximately 0.5 percent of the water filtered (deVarona, 1909).

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*References deVarona (1909), Fuller (1908), Gaub (1915), Karalekas (1952), Mitchell (1921), Saville (1924), and Smith (1945) deal exclusively with slow sand filters. They are included in the operation section as a supplement to information found on intermittent sand filters in some cases and as the only information available about certain areas of operation in other cases.

The most advanced method of cleaning slow and intermittent sand filters was the filter wash machine. This was a device supported by rails along the filter's edge which basically picked up, washed and replaced the sand in one operation using one man (Smith, 1945). There were many variations of this machine; but the most popular seemed to be the Blaisdell, Alen Hagen and Municipal Sand Cleaners (deVarona, 1909; Fuller, 1908; Gaub, 1915; Karalekas, 1952; Mitchell, 1921; Smith, 1945; Streander, 1940). These machines offered the advantages of cleaning the sand down 41 - 46 cm (16 - 18 inches), always having the proper sand depth in the filter, not having to transport the sand from the filter and lower operation costs (Mitchell, 1921). A wash machine could clean 4050 m^2 (1 acre) of bed in three days (Fuller, 1908) as opposed to 11 men cleaning the same area in two days (Saville, 1924). Even with this improvement in operations it remained important to rake the filters between washings (Gaub, 1915; Smith, 1945).

Winter

Winter operations present unique problems to the intermittent sand filter. Biological activity is reduced a great deal by colder temperatures and effluent quality decreases (Anonymous, 1906; Grantham, Emerson and Henry, 1949), but beds are able to accommodate more sewage in winter than summer (Anonymous, 1906) if the BOD_5 loading is moderate (30 mg/l). High BOD_5 concentrations will clog the filters very quickly at temperatures near freezing when compared to run lengths during the summer (deVries, 1972). Winter operations must therefore include lower BOD_5 loading and/or lower hydraulic loading rates (deVries, 1972; McGauhey, 1968). Another problem during winter operation is the sand freezing. Enough water must be applied to the filter to thaw out any frozen sand (Fair, Geyer and Okun, 1968; Metcalf and Eddy, 1935), but not so much that it cannot pass through the filter before freezing itself (Metcalf and Eddy, 1935). These objectives may be reached by loading a filter at 12,628 m^3/ha.d (1.35 MGAD) every third day rather than 4209 m^3/ha.d (0.45 MGAD) each day (Anonymous, 1906). This will also provide longer rest periods to keep the infiltrative capacity of the filter high (McGauhey, 1968).

Filters may be protected from deep freezing by allowing a protective ice cover to form over them. This is accomplished by forming 30 cm (12 inch) furrows in the bed at 1 meter (3 foot) intervals (Anonymous, 1906; Daniels, 1945; Fair, Geyer and Okun, 1968). The ice formed as the filter is loaded will then rest on top of the furrows. This partially insulates the sand from freezing, allows the filter to be loaded under the ice and permits air to circulate freely to the sand surface (Metcalf and Eddy, 1935). It also keeps the ice layer from freezing to the sand and becoming a solid block. This same effect may be achieved by forming piles of the scrapings and leaving them on the filter (Anonymous, 1918; Daniels, 1945; Imhoff, Muller and Thistlethwayte, 1973). When the ice cover melts and the sand thaws, the filter can be cleaned much easier because there is a relatively flat surface to scrape.

Still other variations have been successfully applied. A large operation in Clinton, Massachusetts left most of its filters flat; others were furrowed. The furrowed filters were loaded in extremely cold weather while the normal filters served during milder days (Anonymous, 1906). Use of these ideas and others have proven in the past that filters can be run successfully during freezing conditions.

PERFORMANCE

It is well documented that intermittent sand filters produce effluents of extremely high quality (ASCE - WPCF, 1959; Babbitt and Baumann, 1958; Daniels, 1945). Their major disadvantages lie in the fact that they require relatively large surface areas to perform properly and the cost of sand may be prohibitive (Daniels, 1945). In areas where sand is available, the land needed is less restrictive when viewed in the context of their proposed use. Few, if any, systems will match their complementary nature in polishing stabilization pond effluents. Land is generally available, the filters are easy to operate, no expert is needed to make them function properly and filtrate quality is high. Lagoon systems are also complementary to intermittent sand filters in that they are a secondary treatment system, they can be used in equalizing flows and storing water, silts washed into the system will never reach the filters to cause clogging (Metcalf and Eddy, 1935), they are generally located near open areas of relatively cheap land and their high production periods correspond to the filter's high stabilization periods.

Several authors have noted that the effluent from intermittent sand filters are high in dissolved oxygen, free from settleable solids and free from turbidity, color, odor and iron (Babbitt and Baumann, 1958; Imhoff, Muller and Thistlethwayte, 1973; Story, 1909). Bacterial removal efficiencies run from 95 to 99 percent (ASCE - WPCF, 1959; Anonymous, 1912; Babbitt and Baumann, 1958; Imhoff, Muller and Thistlethwayte, 1973). Some bacteria do pass through the entire bed length, but most are adsorbed in the top 5 cm (2 inches) of the filter where the major head losses occur (Folkman and Wachs, 1970). It has been found, though, that deeper filters will capture more bacteria (Iwasaki, 1937).

Reduction of BOD_5 concentrations is very high. Removals vary from 90 to 100 percent (Babbitt and Baumann, 1958; deVries, 1972; Imhoff, Muller and Thistlethwayte, 1973) and the mean effluent concentration is less than 10 mg/l (ASCE - WPCF, 1959). This removal increases with increasing temperature due to greater biological activity within the filter (Grantham, Emerson and Henry, 1949). Hydraulic loading rate increases seem to lower the removal efficiency of BOD_5 (Grantham, Emerson and Henry, 1949).

Suspended solids removal is dependent on effective sand size (Grantham, Emerson and Henry, 1949) and bed depth (Iwasaki, 1937). Most filters will achieve a 90 - 95 percent reduction in SS (ASCE - WPCF, 1959; Babbitt and Baumann, 1958; Salvato, 1955). Bailey (1937) reported on the use of anthrafilt as a filtering medium in slow sand filters and found that over time the sand was more successful. However, suspended solids removal for both mediums were comparable.

Nitrification is one of the major biological functions in an intermittent sand filter (Metcalf and Eddy, 1935; Salvato, 1955; Story, 1909). Effluent nitrate concentrations will run between 3 to 20 mg/1 (ASCE - WPCF, 1959) with almost no ammonia (Babbitt and Baumann, 1958; deVries, 1972). Lower loading rates, smaller sand sizes and higher temperatures all tend to favor more complete nitrification (deVries, 1972; Grantham, Emerson and Henry, 1949).

Metcalf and Eddy (1935) have noted that too coarse a sand will result in rapid filtration with deep (or complete) penetration of SS and too short a contact time. On the other hand, a sand that is too fine will limit the hydraulic loading rate and decrease aeration time so that the filter fails. These facts limit sand sizes to those given in the design section.

Some possible disadvantages in performance should also be noted. Effluent quality remains high, but is lowered by cold weather when removal efficiencies decrease and nitrification is slowed (Anonymous, 1906; Metcalf and Eddy, 1935). Because of the need to scrape, clean and aerate the filters for proper operation they can be down as much as 13 percent of the time (Fuller, 1908). Algal cell removal may also be highly variable. Four separate studies showed that algae do pass through the entire bed depth (Borchardt and O'Melia, 1961; Folkman and Wachs, 1970; Ives, 1961; Marshall and Middlebrooks, 1974). Borchardt and O'Melia (1961) found a 20 - 40 percent removal of Scenedesmus, Ankistrodesmus and Anabaena through effective sand sizes of 0.316, 0.397 and 0.524 mm. Teir hydraulic loading rates were very high 116,930 - 1,169,300 m^3/ha.d (12.5 - 125 MGAD), but loading rate variations did not seem to effect cell removal. Sand size was a factor with smaller sizes being more effective. Folkman and Wachs (1970) found that one lagoon genus in Israel, Chlorella sp., divided into daughter cells in darkness and escaped permanent capture within the filter. Ives (1961) reported a 100 percent removal of Scenedesmus and a 97 percent removal of Chlorella in his studies using radioactive cells and a different sand than that used in Israel. Marshall and Middlebrooks (1974) reported that Chlamydomonas sp. was the major algae species present in their studies, and that the cells passing through the filter bed were mostly dead. All of the studies showed that a smaller effective size sand achieved better algae removal than larger sands, but that cell penetration occurs through even the smallest size.

ECONOMICS

Metcalf and Eddy (1935) state that filter construction costs can vary a great deal depending on the availability of suitable filter material, the length of material haul, the degree of preparation needed for the material, site preparation needed and the underdrain system utilized. Operation costs may also vary depending on the need to remove accumulated solids (scrape the filters), renew the sand, renew and repair the underdrains, pump effluents to the bed and upkeep embankments and grounds.

A summary of historic costs associated with slow sand and intermittent sand filters was reported by Marshall and Middlebrooks (1974). Several references dealing with filter costs were cited (Anonymous, 1914; Fuller, 1914; Powell, 1911; Saville, 1924; Story, 1909) and the Engineering News Record Cost Indices were used to update costs to 1972 values. Based upon those early costs, filter construction costs were estimated to be $622,699/hectare ($252,000 per acre) of sand bed and operation costs would vary from $8 to $37 per 1000 m^3 ($30 to $140 per million gallons - MG) of wastewater treated. Labor costs were estimated to account for approximately 80 percent of the cost of operation because of the need to rake, scrape, wash the sand, resand, smooth and generally maintain the filters.

Marshall and Middlebrooks (1974) also prepared cost estimates with the aid of a local engineering consultant using present day (1972) techniques and values. Cost estimates were based on two assumptions: 1) that no pumping would be needed for the operation of the filters, and 2) that the filters would be located in the final compartments of an existing lagoon system with land purchase unnecessary. Using these assumptions, local material costs and 75 percent federal funding of construction; a 2806 m^3/ha.d (0.3 MGAD) plant treating 3786 m^3 (1 MGD) of pond effluents would cost community $96,200 to construct. Using a 20 year economic life span, treatment would cost $12.42/1000 m^3 ($47/MG) if federal assistance was received and $30.40/1000 m^3 ($115 per MG) if federal assistance was not available. Designing filters to treat 7484 m^3/ha.d (0.8 MGAD) rather than 2806 m^3/ha.d (0.3 MGAD) would lower this estimate to $4 and $12.70 per 1000 m^3 ($15 and $48 per MG) of wastewater filtered with and without federal assistance, respectively.

Comparing these costs to alternative methods of polishing wastewater effluents in Table 2 shows that intermittent sand filtration is a very competitive process.

SUMMARY

A review of literature describing the need for, and possible methods of, upgrading lagoon effluents with the conclusion that the intermittent sand filter could meet this need has been presented. The history, recent investigative developments, theory, design, operation, performance and economics of the intermittent sand filter has also been reviewed. Each of these areas indicate that intermittent sand filtration may be a viable process for wastewater effluent polishing.

This study will utilize the information gained from the literature to construct and operate a prototype filter system and determine the feasibility of its use on a full scale. The study will also afford an opportunity to evaluate filter performance under natural conditions.

TABLE 2. COST OF ALTERNATIVE METHODS OF POLISHING WASTEWATER EFFLUENTS (MARSHALL AND MIDDLEBROOKS, 1974)

Method	Cost Per 10^6 Gallons
Chemical treatment (solids contact)	\$60-130
Granular or mixed media filtration w/chem	\$ 50
Dissolved air flotation	\$110
Electrodialysis	\$200
Microstraining	\$ 18
Intermittent sand filters	\$115

10^6 Gal. = 3785 m^3

SECTION 5

METHODS AND PROCEDURES

EXPERIMENTAL FACILITY

A prototype filter system was constructed near the discharge point of the Logan City Wastewater Stabilization Ponds. These are located some three miles west of the City of Logan, Utah as shown on Figure 1. The location of the filters made it possible to utilize either secondary or tertiary effluents from these ponds.

The facility consists of six 7.6 x 11 meter (25 x 36 ft) intermittent sand filters with their attendant loading equipment. A cross section of a typical filter is shown in Figure 2. The filters were constructed using compacted lifts of bank run granular fill material. They each contain 0.3 meters (1 foot) of graded gravel composed of 12.7 cm of 3.8 cm maximum diameter rock, 7.6 cm of 1.9 cm maximum diameter rock and 10.1 cm of 0.6 cm maximum diameter rock (5 inches of 1 1/2 in. maximum diameter rock, 3 inches of 3/4 in. maximum diameter rock and 4 inches of 1/4 in. maximum diameter rock). Bedded within the graded gravel are three flexible drain pipes. One meter (3 ft) of pit run concrete sand was placed over the gravel. The sand has an effective size of 0.17 mm and a uniformity coefficient of 9.74. The sand sieve analysis is shown in Table 3. A vinyl liner (10 mm) was placed in each filter to prevent infiltration of groundwater and exfiltration of filtrate. Freeboard above sand level allowed a maximum head of 1 meter (3 ft) to be loaded on each filter. In an attempt to monitor head loss, tubes were buried in each filter at depths of 15.2, 30.5, 61 and 91.4 cm (1/2, 1, 2 and 3 feet). Troughs made of sheet metal (0.3 x 0.3 x 4.6 m or 1 x 1 x 15 feet) were also placed in the filters to prevent sand erosion and scouring.

Filter loading was accomplished, using a manually primed, centrifugal pump.* The pump discharged approximately 4.90 (10^{-2}) m^3/sec (1.73 cfs) against a static head of some 2.5 meters (3 ft). Pump flow was measured using an in-line, impeller flow meter.† Water was directed to each filter through a manifold valve

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*Centrifugal pump--Berkeley Pump; Model - 1-wp, H.P. - 5, B.M. No. - 51956, Serial - 7479813.

†Rockwell Flowmeter, Pittsburg, Pa., Serial No. 6873.

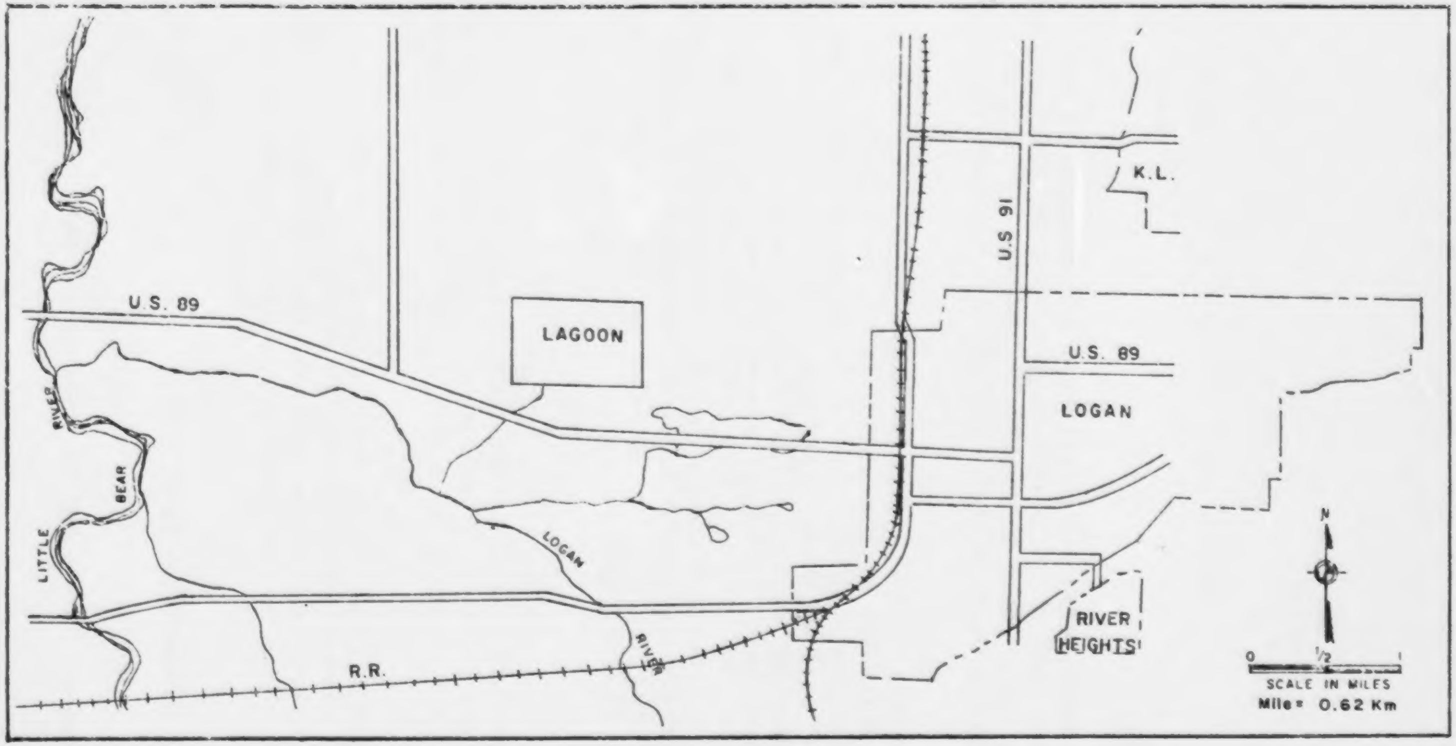
U.S. 89
LAGOON
U.S 91
K.L.
U.S. 89
LOGAN
LITTLE
BEAR
RIVER
LOGAN
RIVER
R.R.
RIVER
HEIGHTS
N
0
½
1
SCALE IN MILES
Mile = 0.62 Km

Figure 1. Map showing the location of the lagoon treatment system for the City of Logan, Utah.

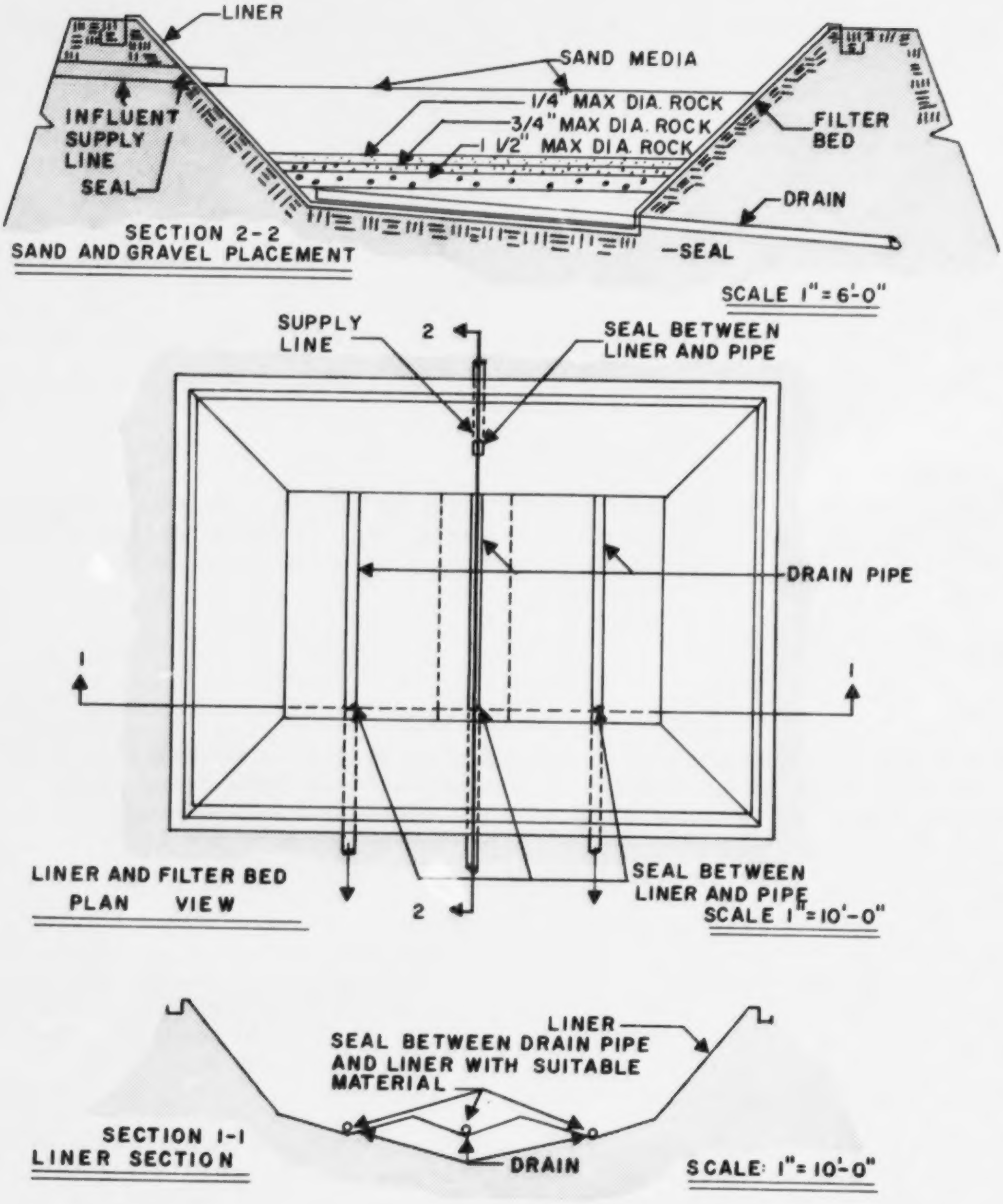
LINER
SAND MEDIA
1/4" MAX DIA. ROCK
3/4" MAX DIA. ROCK
1 1/2" MAX DIA. ROCK
INFLUENT SUPPLY LINE
SEAL
FILTER BED
DRAIN
SEAL
SECTION 2-2
SAND AND GRAVEL PLACEMENT
SCALE 1" = 6'-0"
SUPPLY LINE
2
SEAL BETWEEN LINER AND PIPE
DRAIN PIPE
1
1
LINER AND FILTER BED
PLAN VIEW
2
SEAL BETWEEN LINER AND PIPE
SCALE 1" = 10'-0"
LINER
SEAL BETWEEN DRAIN PIPE AND LINER WITH SUITABLE MATERIAL
SECTION 1-1
LINER SECTION
DRAIN
SCALE: 1" = 10'-0"

Figure 2. Side plan and front view of a typical intermittent sand filter. (1 inch = 2.54 cm and 1 foot = 0.3048 m.)

TABLE 3. SIEVE ANALYSIS OF FILTER SAND USED IN THE STUDY*

U. S. Sieve Designation Number	Size of Opening (mm)	Percent Passing (%)
3/8"	9.53	100.0
4	4.76	92.1
10	-	61.7
40	0.42	27.0
100	0.149	6.2
200	0.074	1.7

*Effective size = 0.170 mm; Uniformity coefficient = 9.74; 1 inch = 2.54 cm.

arrangement located in the pump house. The pump capacity allowed a hydraulic loading rate of 9354.4 cubic meters per hectare-day (m^3/ha.d) or 1.0 million gallons per acre-day (MGAD) to be loaded on a filter in approximately 25 minutes.

FILTER OPERATION

General

Because of the experience of Marshall and Middlebrooks (1974) in using pit run concrete sand, it was decided to ''wash-out'' the fines after filter construction. This was done by applying approximately 14,967 m^3/ha.d (1.6 MGAD) of tertiary lagoon effluent to each filter for a period of one to two weeks. No formal sampling was performed during this washing period.

Following this initial washing period each filter was loaded once daily (usually early in the morning) with tertiary or secondary pond effluent. After a short time it was clear that the highest suspended solids concentrations were found in the secondary lagoon effluent and filter influent was taken almost completely from that source. When the total influent applied to a filter did not completely drain to at least the sand surface in a 24 hour period the filter was considered plugged and it was taken out of service.

Filter cleaning was accomplished by scraping off the top 2.5 to 5 cm (1 to 2 inches) of sand using shovels. The filter was usually given a period of time to rest and dry out before scraping. The surface was then leveled and smoothed before starting another cycle. By doing this the filter's service life was completely renewed for the next filter run. Scrapings removed from the filters were stockpiled close at hand for eventual cleaning and replacement.

This project was undertaken to evaluate the effluent quality of a given size sand at different hydraulic loading rates. These rates were initially set at 1871, 3742, 5613, 7484, 9354 and 11,225 m^3/ha.d (0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 MGAD). After a short time this was modified so that the effects of raking the filter surface after plugging could be evaluated when compared to removal of the sand. The 11,225 m^3/ha.d (1.2 MGAD) loading rate was reduced to 9354 m^3/ha.d (1.0 MGAD) and the filter's surface raked after plugging.

Secondary lagoon effluent was taken from a bottom drain valve in the secondary pond. Two separate suspended solids analyses were run on this effluent to determine if its quality varied after the valve was opened. It was found that the suspended solids concentrations did start high and then decrease to an average. This was probably due to sedimentation near the valve opening. It was decided from this analysis to open the valve for 1/2 hour before pumping to the filters. This precaution insured an equal influent to each filter.

Winter

During the winter experimental period a hydraulic loading rate of 3742 m^3/ha.d (0.4 MGAD) was applied to four of the six filters (one remained at 1871 m^3/ha.d (0.2 MGAD) loading, one was out of service). It was anticipated that cold weather and freezing would create serious winter operational problems. In an attempt to find the best method, four separate operational modes were studied. The first mode utilized the furrow technique described in the literature. The second operational mode involved placing 0.3 meter (1 foot) wooden stakes at 1.2 meter (4 ft) centers across the filter surface to break up any ice sheets which formed. The third method involved maintaining at least 0.3 meters (1 foot) of water standing on the filter at all times (flooding like a slow sand filter because biological activity would be low). The fourth operational mode was the control and involved making no changes in the filter operation or configuration.

The problem of keeping the pump facility from freezing was solved by installing heaters. Pipes leading from the manifold to the filters were exposed and were therefore opened and drained after loading the filters.

SAMPLING

Samples were taken once each week for influent and effluent analyses. There were some occasions during the irrigation season when the filter effluent pipes were inundated. Effluent samples could not be taken at these times.

A good deal of effort was expended to develop standard sampling procedures so that the best possible results could be achieved. The plastic gallon containers used for taking samples were cleaned and rinsed before use as well as rinsed with the sample itself. All effluent ports were scrubbed of sediment and algae growth to insure that samples were not contaminated. Equal amounts of effluent were taken from each of the drain pipes in each filter. Laboratory analyses were begun on the samples within approximately 2 hours of collection and filter effluent samples were always taken two hours after loading.

A procedure was also practiced for starting up a filter after it had been cleaned in relation to when it would first be sampled. During the summer and fall periods effluent samples were collected the first day a filter was loaded after cleaning. It was later decided to start loading the day before sampling. This procedure was carried out during the rest of the year.

All sample temperatures and dissolved oxygen (DO) readings were made in situ. An electronic dissolved oxygen meter* was used most of the time. This was occasionally calibrated the night before, but generally it was calibrated the morning of sampling. There were some weeks when dissolved oxygen was measured using the Winkler test directly (APHA, AWWA, WPCF, 1971). Sample pHs† were taken at the filters most of the year.

LABORATORY ANALYSIS

Collected influent and effluent samples were analyzed for five day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), suspended solids (SS), volatile suspended solids (VSS), total phosphorus (Total P), orthophosphate ($O\text{-}PO_4\text{-}P$), ammonia ($NH_3\text{-}N$), nitrite ($NO_2\text{-}N$), nitrate ($NO_3\text{-}N$), pH, temperature and dissolved oxygen. All of these tests were completed within three days of sampling (except BOD_5).

Influent and chosen effluent samples were also analyzed for algae identification and quantification. These samples were read the day after sampling most of the time. All of the samples were stained and preserved using a Merthiolate solution and then stored at 4°C in darkness (APHA, AWWA, WPCF, 1971). A Sedgwick-Rafter Counting Cell was used under a magnification of 200x for counting.

Data analysis was performed using a Burroughs 6500 Computer at the Utah State University Computer Center and the Control Data Corporation 6400 and 6600 Computer located at the University of Texas in Austin, Texas.

The procedure employed for each chemical and biological analysis is given in Table 4.

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*Dissolved oxygen meter--Model 54 oxygen meter, Yellow Springs Instrument Co., Inc., Yellow Springs, Ohio.

†pH Meter--Beckman Zeromatic II, Model 96A, Beckman Instruments, Inc., Fullerton, California.

TABLE 4. PROCEDURES FOR ANALYSIS PERFORMED

Analysis	Procedure	Ref. No.
Biochemical Oxygen Demand	Standard Methods	APHA, AWWA, WPCF, 1971
Chemical Oxygen Demand	Standard Methods	APHA, AWWA, WPCF, 1971
Suspended Solids	Standard Methods	APHA, AWWA, WPCF, 1971
Volatile Suspended Solids	Standard Methods	APHA, AWWA, WPCF, 1971
Total Phosphorus	E.P.A. Methods	EPA, 1971
Orthophosphorus	Strickland and Parsons (Murphy-Riley Technique)	Strickland & Parsons, 1968
Ammonia	Solorzano (Indophenol)	Solorzano, 1969
Nitrite	Strickland and Parsons (Diasotization Method)	Strickland & Parsons, 1968
Nitrate	Strickland and Parsons (Cadmium-Reduction Method)	Strickland & Parsons, 1968
Dissolved Oxygen	Standard Methods	APHA, AWWA, WPCF, 1971
Temperature	Standard Methods	APHA, AWWA, WPCF, 1971
pH	Standard Methods	APHA, AWWA, WPCF, 1971
Cell Counting	Standard Methods	APHA, AWWA, WPCF, 1971

SECTION 6

RESULTS AND DISCUSSION

GENERAL

Filter loading and data collection began July 2, 1974 and ran continuously through June 27, 1975. The data presented in this report are an overall view of the performance of the sand filters, a seasonal performance analysis, a warm weather versus freezing weather evaluation and a hydraulic loading rate evaluation. The data for the winter experimental period were collected between December 23, 1974 and March 24, 1975.

Filter performance was determined on the analysis of grab samples of filter effluent. It was recognized that unless filter effluent quality was constant with respect to time, grab samples would not adequately represent filter performance. To determine the variability of filter effluent quality with time, measurements of filter effluent quality with time were conducted at the beginning of the study on July 29, 1974, and mid-way through the study on February 20, 1975. A comparison of the suspended solids performance of a typical filter for both sample days is shown in Figure 3.

On July 29, 1974, effluent suspended solids concentration was the only effluent quality parameter which varied significantly with time. As shown in Figure 3, on July 29, 1974, the peak in effluent suspended solids concentration occurred at approximately 20 minutes after the filter was loaded. This peak in effluent suspended solids was probably caused by high fluid velocities within the sand filter bed which are a result of the initial maximum hydraulic head on the filters. The filter sand was not washed prior to installation in the filters. Thus, these high velocities cause an initial ''wash out'' of the fine silt or dirt within the sand filter media. This conclusion is verified by the fact that at no time did the filter effluent volatile suspended solids concentration on July 29, 1974, exceed 1 mg/l. Also, after the initial ''wash out'' period was completed (several months prior to February 20, 1975), the filter effluent suspended solids concentration with time did not vary significantly with time (Figure 3).

The measurements taken with time on February 20, 1975, indicated that none of the parameters varied significantly with time. The results of the samples from February 20, 1975, are recorded in Appendix A, Table A-3-1.

In order to obtain an effluent grab sample which was not biased by the initial ''wash out'' of fine silt and which represented the filter effluent, it was decided to collect the filter effluent grab samples approximately two hours after the filters were loaded.

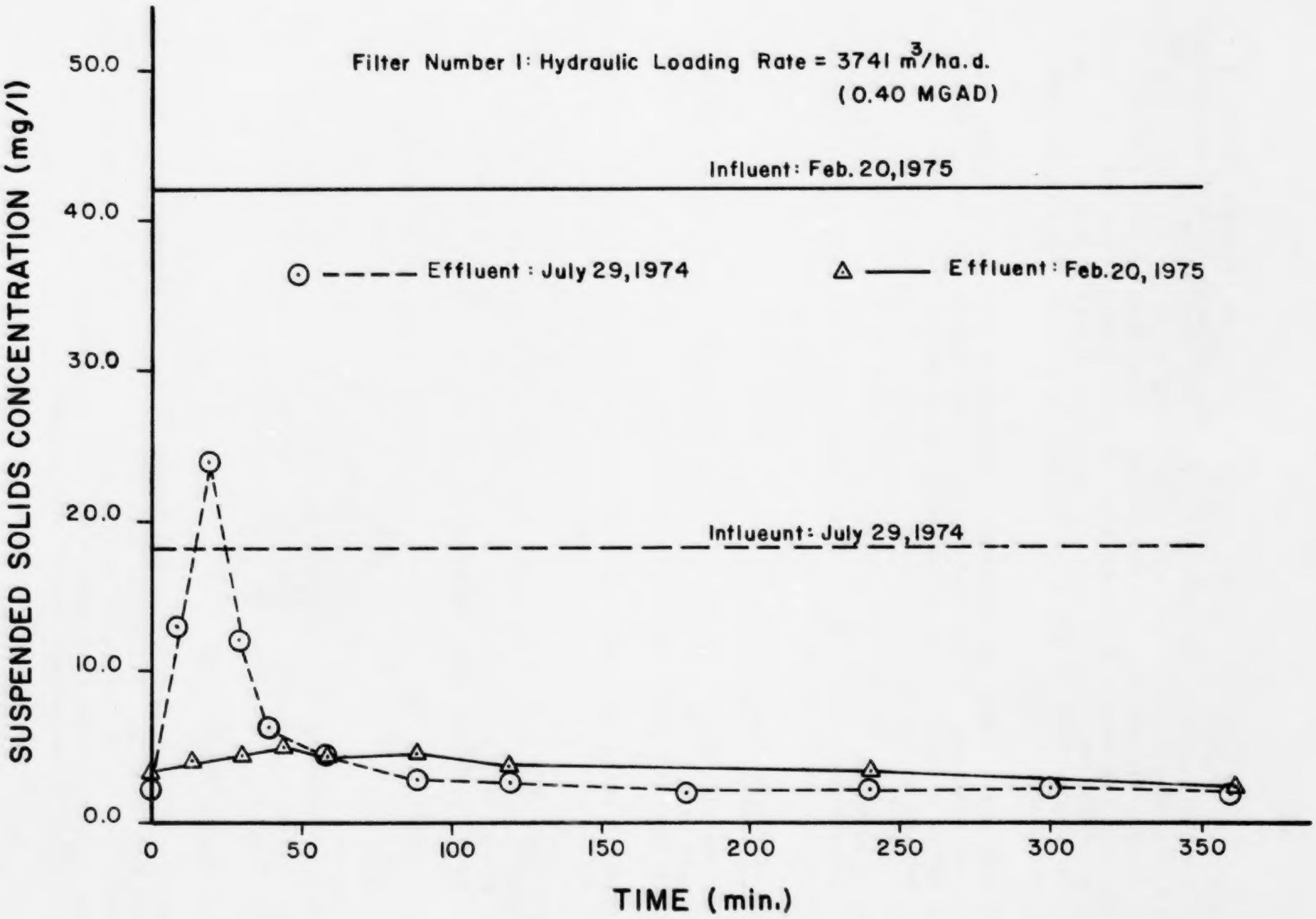


Figure 3. Typical effluent suspended solids performance with time.

PARAMETER ANALYSIS

The plots of this section are an aid to visualize the data listed in Appendix A-1. Figures 4 to 15 graphically show influent loading and effluent values for each sampling day during the year. The dashed vertical lines mark the plugging of a filter. The data points found between these lines show filter performance trends for each run period. These figures also present a comparison of the length of filter runs for each loading rate and each season. As was mentioned earlier, all filters but number 6 were loaded at 3742 cubic meters per hectare-day (m^3/ha.d) or 0.4 million gallons per acre-day (MGAD) during the winter months.

The data are discussed in terms of filter run averages, seasonal averages, and overall averages. Filter run average is defined as the average value obtained during a specific filter run period between pluggings. Seasonal average is defined as average value obtained for the seasons of the year, namely summer (June 26 to September 20), fall (September 26 to December 19), winter (December 26 to March 20), and spring (March 27 to June 19). The overall average is defined as the average value obtained from all of the data collected throughout the entire study.

Biochemicl Oxygen Demand (BOD_5)

The overall influent average for this parameter was 19 mg/l. Influent BOD_5 ranged from a low of 4 mg/l to a high of over 288 mg/l. Influent BOD_5 concentrations exceeded 5 mg/l over 90 percent of the time.

Figure 4 shows the consistent high quality of filter effluent, which seemed almost unaffected by influent fluctuations. Effluent quality was below 5 mg/l over 90 percent of the time with all effluent BOD_5 filter run averages, seasonal averages and overall averages less than 5 mg/l (except filter number 2 during the winter season). Effluent BOD_5 concentrations never exceeded 12 mg/l on any filter (except filter number 2 during the winter season) and exceeded 7 mg/l only 4 times (number 6 once, number 4 twice, number 1 once).

It is worthy to note the operation of filter number 2 during the winter season. This filter was constantly flooded during winter seasons. The anaerobic conditions that developed in filter number 2 greatly reduced this filter's efficiency. Filter number 2 effluent BOD_5 concentration exceeded 5 mg/l over 90 percent of the time. At the end of the winter season this filter was returned to normal loading. After this time the filter's effluent quality returned to normal when compared to the other filters.

Chemical Oxygen Demand (COD)

The pattern for chemical oxygen demand (Figure 5) removal was similar to that for BOD_5 removal. Filter effluent COD concentrations increased slightly with increases in the hydraulic loading rate. As with other parameters, winter effluent concentrations increased some. The effluent from filter number 2 during the winter season was significantly higher.

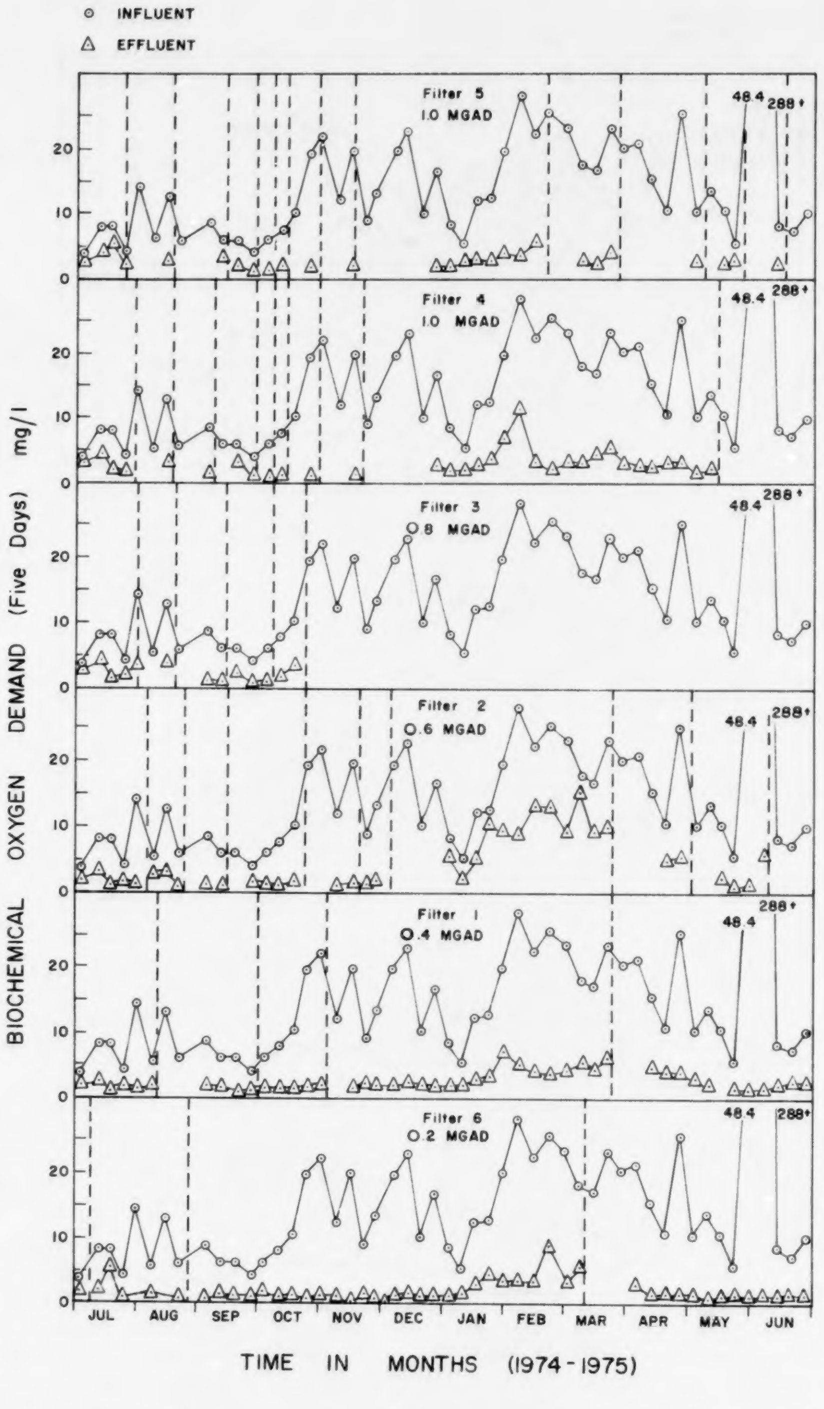


Figure 4. Filter biochemical oxygen demand performance plots separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

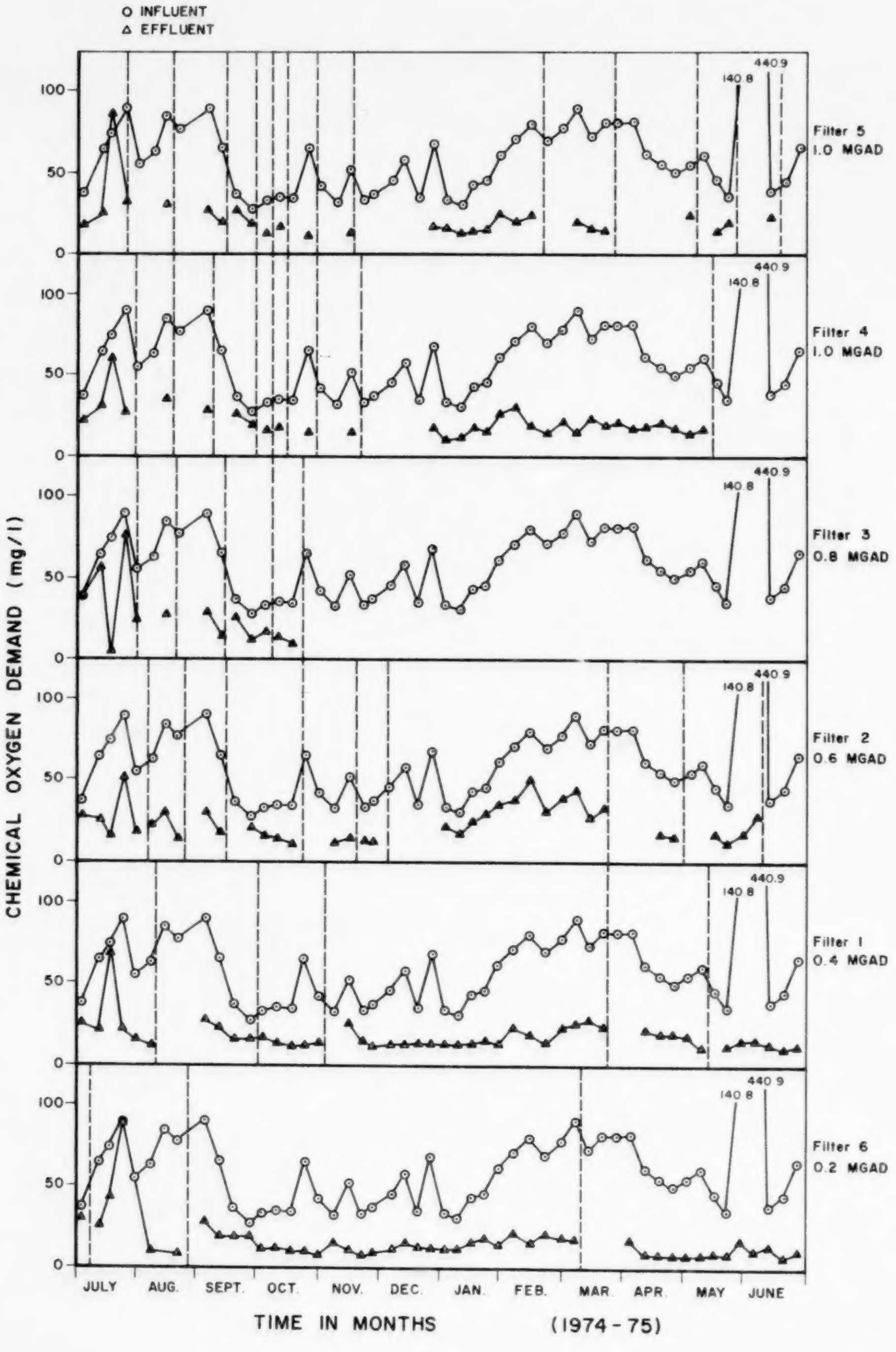


Figure 5. Filter chemical oxygen demand performance plots separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

The overall average influent COD was 66 mg/l, while the effluent COD overall averages ranged from 16 mg/l from filter number 6 to 25 mg/l from filter number 2. Data on a daily basis show the effluent to be 1/3 to 1/2 the influent COD concentration. At the maximum COD influent concentration of 440 mg/l the filter effluent COD concentrations ranged from 10 in filter number 6 to 30 mg/l in filter number 2.

Suspended Solids (SS)

Suspended solids (SS) performance of the filters is shown in Figure 6. Influent SS concentrations exceeded 5 mg/l suspended solids 100 percent of the time and was greater than 30 mg/l over 40 percent of the time. The overall average of SS applied was 31 mg/l with a low single value of 6 mg/l and a high single value of 130 mg/l. The three filters in operation at the time of maximum influent suspended solids (130 mg/l) had effluent concentrations of less than 3 mg/l suspended solids.

Even with the initial washing period before actual filter operation was begun, the first few effluent suspended solids concentrations were relatively high (exceeded influent concentrations). After these inorganic fines were ''washed'' from the filters, effluent concentrations were less than 5 mg/l suspended solids over 80 percent of the time and had overall averages of less than 6 mg/l for all filters. After the initial ''wash out'' period, the effluent from all filters (except filter number 2 during the winter) exceeded 10 mg/l on only 6 occasions out of 207 samples taken. The anaerobic condition of filter number 2 during winter operations caused its effluent to exceed 5 mg/l over 80 percent of the time.

Volatile Suspended Solids (VSS)

The removal pattern of volatile suspended solids closely followed that of suspended solids. Because of the washing out process of inorganic fines, volatile suspended solids in filter effluents were not as erratic during the first few sample days as suspended solids.

Influent volatile suspended solids exceeded 5 mg/l over 90 percent of the time (Figure 7). Influent VSS averaged 24 mg/l over the entire year with a low single value of 3 mg/l and a high single value of 109 mg/l. On the day of maximum influent VSS concentration the three filters in operation had effluent concentrations of less than 2 mg/l VSS.

Effluent volatile suspended solids concentrations were below 5 mg/l over 90 percent of the time and never exceeded 9 mg/l on any filter during the entire year. Overall effluent averages were less than 3 mg/l for all filters. Figure 7 shows that filter number 2 is again the exception during winter operation. It exceeded 5 mg/l 67 percent of the time.

Total Phosphorus (Total P)

Total phosphorus performance is shown in Figure 8. Overall average values indicate that a slight removal of total phosphorus from filter influents was achieved. Total phosphorus effluent overall averages ranged from 2.4 mg/l

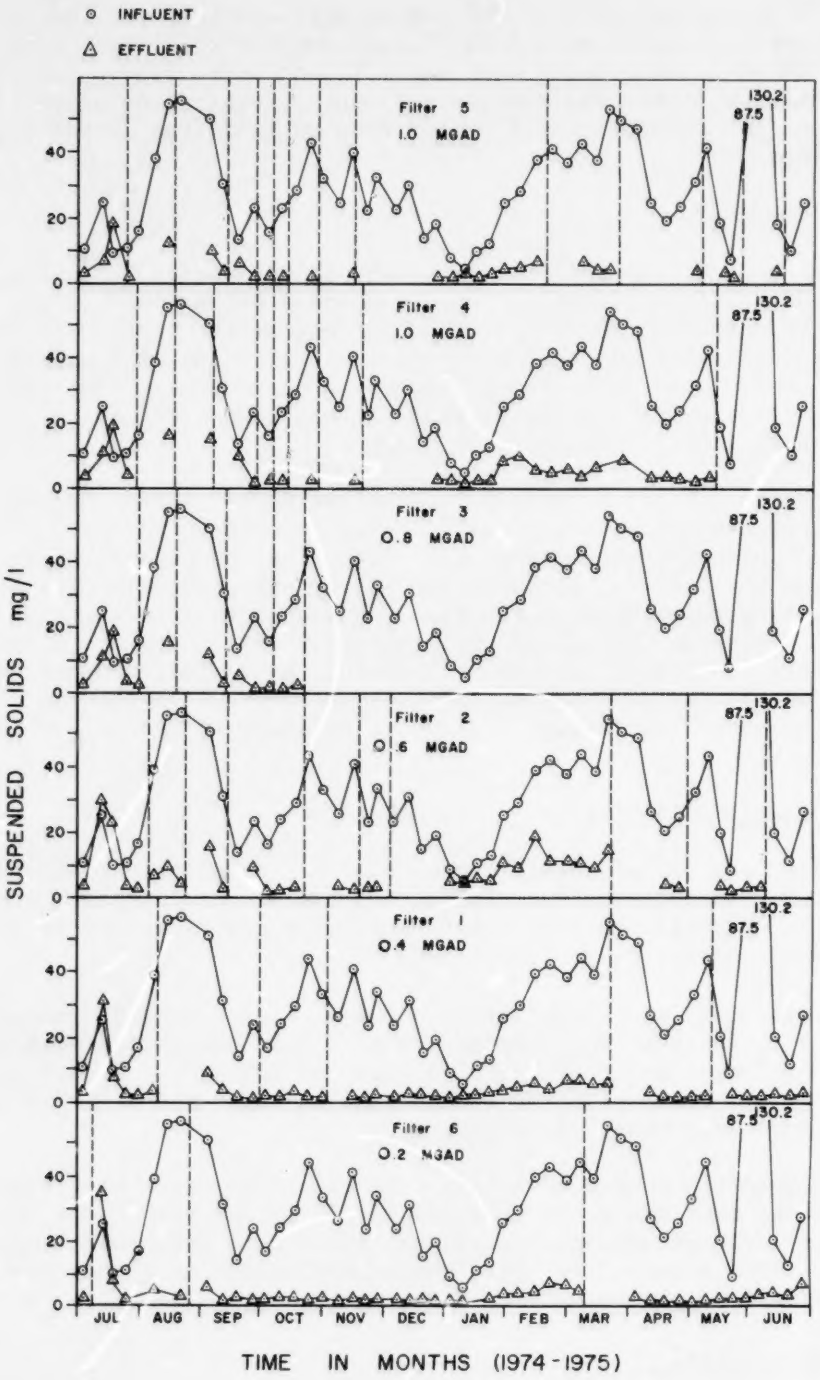


Figure 6. Filter suspended solids performance plots separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

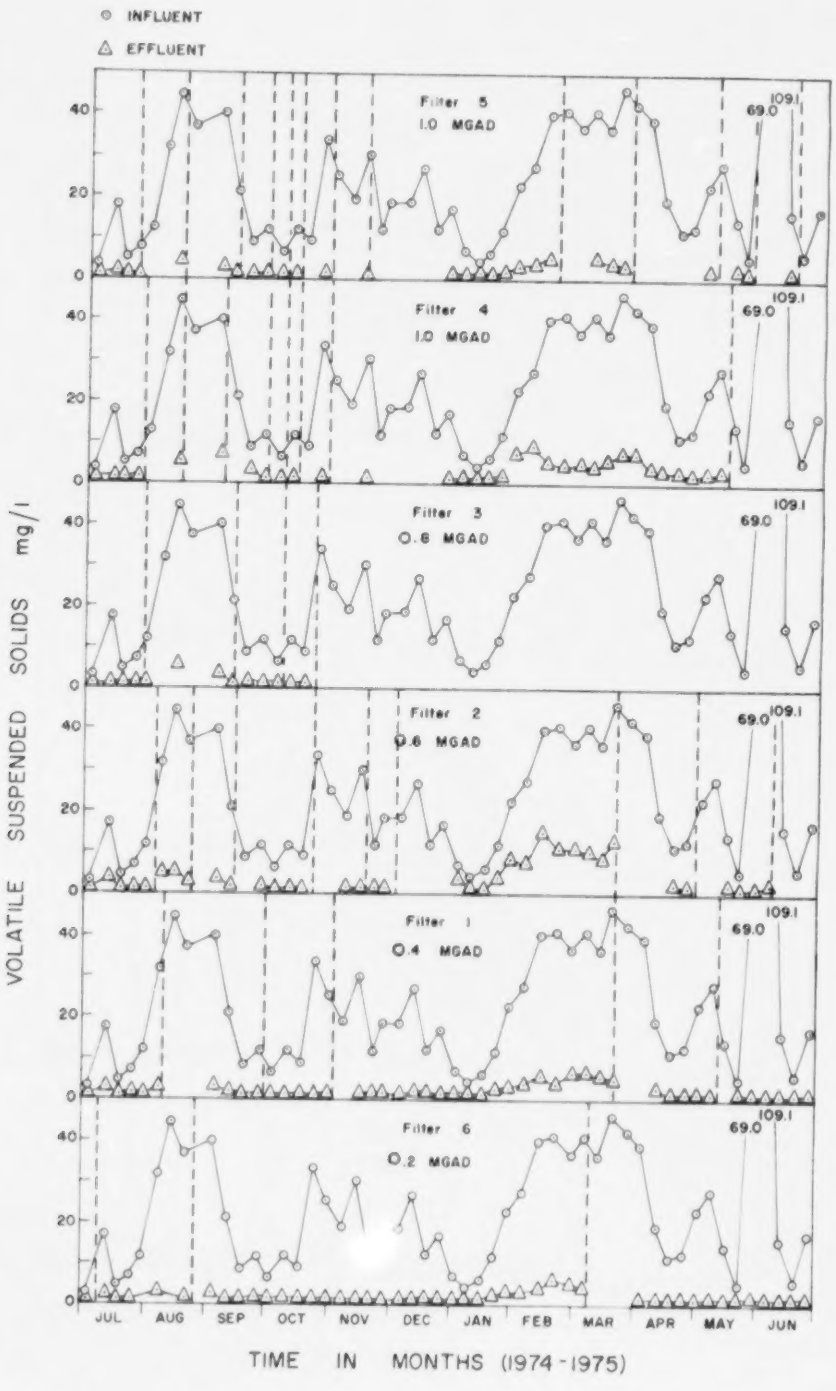


Figure 7. Filter volatile suspended solids performance plots separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

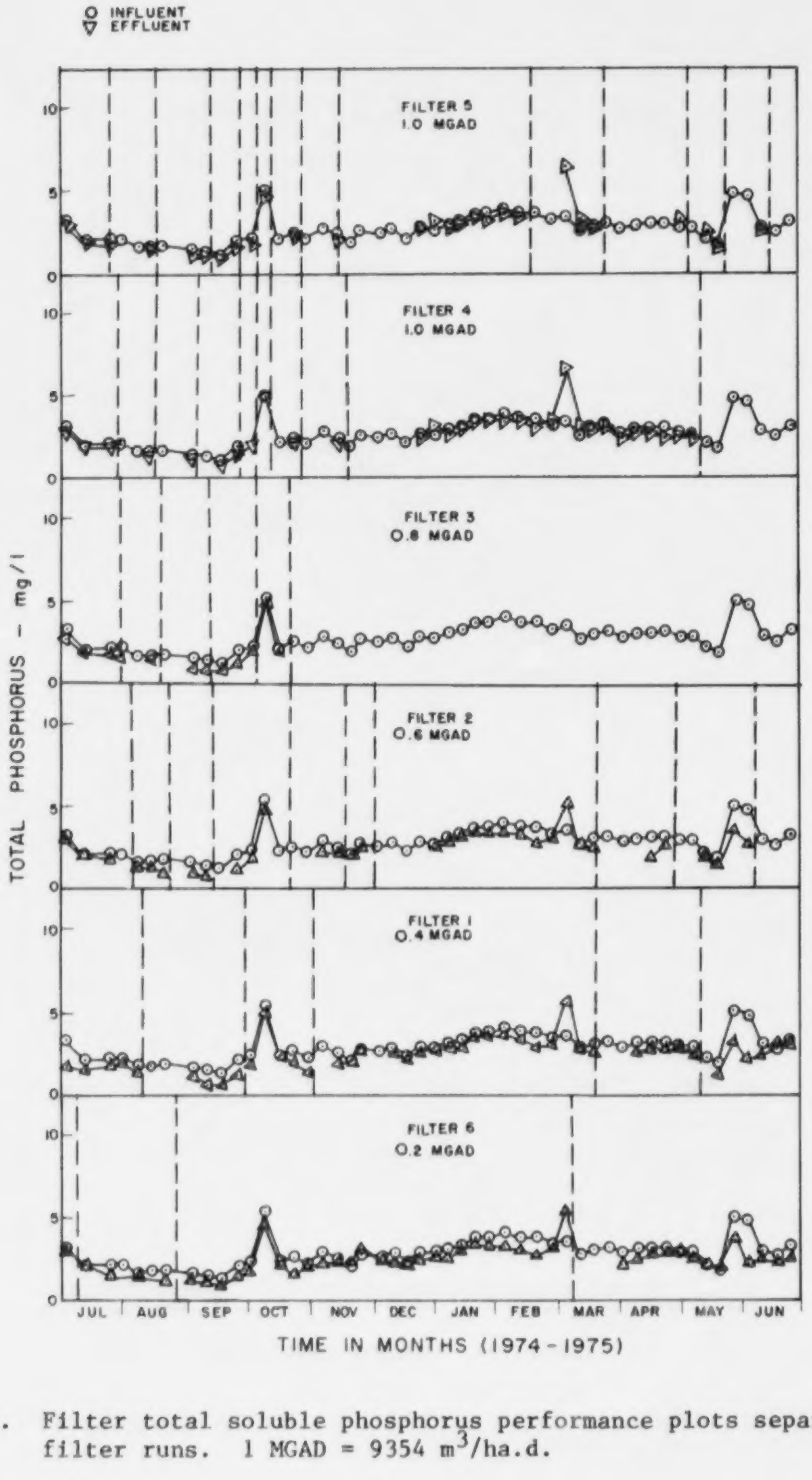


Figure 8. Filter total soluble phosphorus performance plots separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

(filter number 1) to 2.7 mg/l (filter number 4) while the influent overall average concentration was 2.9 mg/l. The effluent concentrations of March 6, 1975, and October 10, 1975, shown in Figure 8 are highly suspect and may be due to analytical error.

Results discussed later indicate that phosphorus removal is dependent on both hydraulic loading rate and seasonal temperature variations. The removal mechanism is very likely a combination of adsorption on sand particles and an uptake by filter bacteria. Thomas, Schwartz, and Bendixen (1966) have reported similar findings with wastewater applied directly to soil.

Orthophosphate as Phosphorus ($O\text{-}PO_4\text{-}P$)

Orthophosphate removal performance is shown in Figure 9. The influent orthophosphate summer average is 1.7 mg/l while effluent summer averages range from 1.8 mg/l (filter number 6) to 1.4 mg/l (filters number 1 and 2). Filter number 6 which was loaded at 1871 m^3/ha.d (0.2 MGAD) is the only filter whose effluent summer average (Figure 19) is above the influent summer average. Summer averages (Figure 19) generally show a decrease in effluent ortho-phosphorus concentration which could be from adsorption on sand particles. The slight increase in effluent ortho-phosphorus concentrations during the winter (winter influent average was 2.9 mg/l and effluent averages ranged from 2.9 mg/l (filter number 6) to 3.1 mg/l (filter number 5) for filters 1, 4, 5, and 6) may be due to the hydrolysis of total phosphorus to orthophosphate or phosphorus released from declining bacterial populations. It may also be due to a release of adsorbed orthophosphate from changes in the adsorption capacity of the sand due to lower temperatures. The effluent ortho-phosphorus concentration for filter number 4 on March 6, 1975, is suspect and may be due to analytical error.

Ammonia as Nitrogen ($NH_3\text{-}N$)

Nitrification is a major stabilization process within the filters. It can readily be seen from Figure 10 that ammonia is significantly reduced through each filter. The warm weather (July 2, 1974, to December 23, 1974, and March 25, 1975, to June 27, 1975) NH_3-N effluent average for each filter was below 0.6 mg/l NH_3-N while the corresponding influent average was 2.9 mg/l NH_3-N. During the cold weather months (December 23, 1974, to March 24, 1975) this bacterial action decreased as would be expected.

Nitrification was absent in filter number 2 while the filter was anaerobic during the winter period (December 26, 1974, to March 20, 1975). Ammonia concentrations in the effluent of filter number 2 were similar to that of the lagoon effluents (4.6 mg/l winter filter effluent average as compared to 5.0 mg/l winter lagoon effluent average).

There is a slight increase in effluent ammonia concentrations as hydraulic loading is increased (Figure 18). With greater head the water is forced to move through the filter more rapidly, reducing the time of contact for the oxidation of ammonia to nitrite.

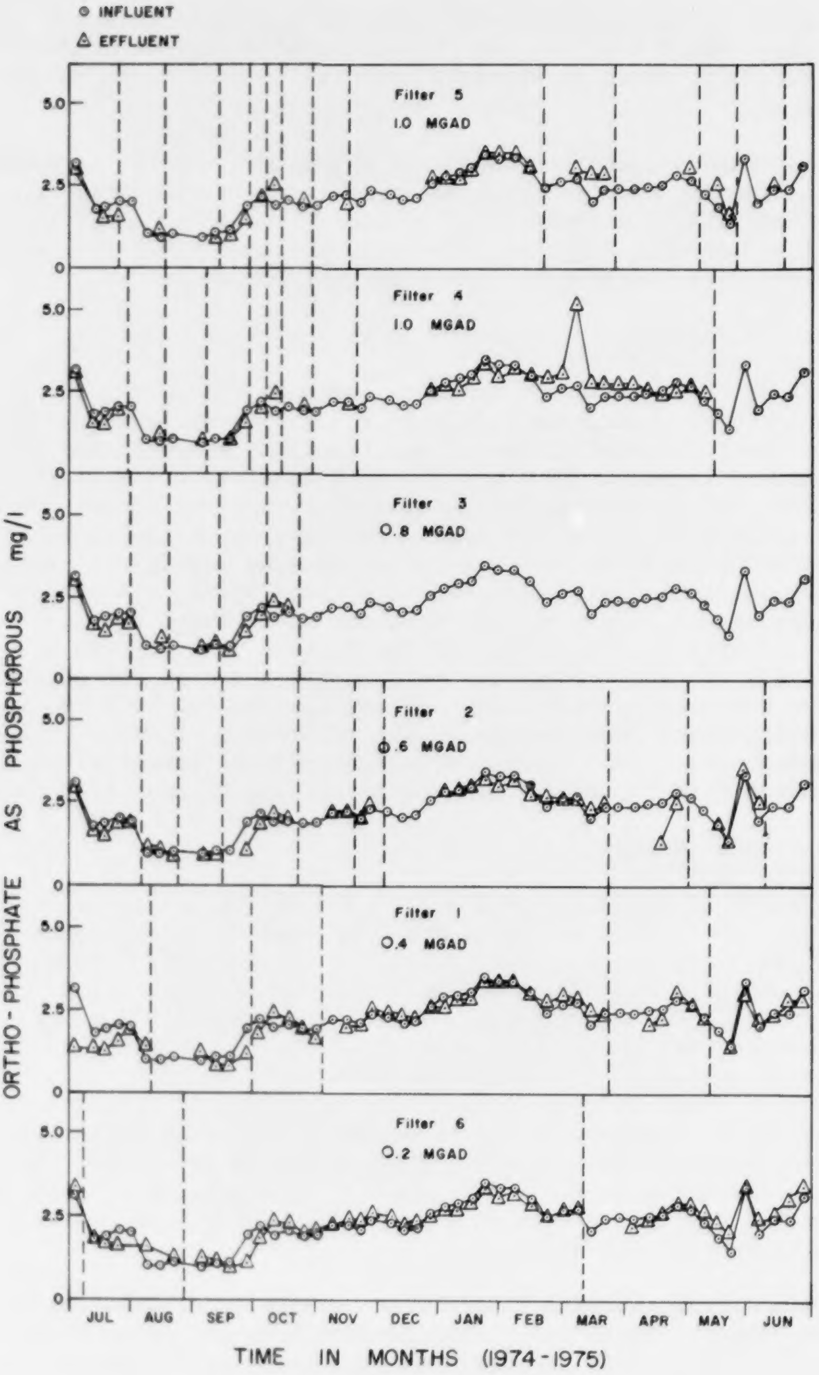


Figure 9. Filter orthophosphate-phosphorus performance plots separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

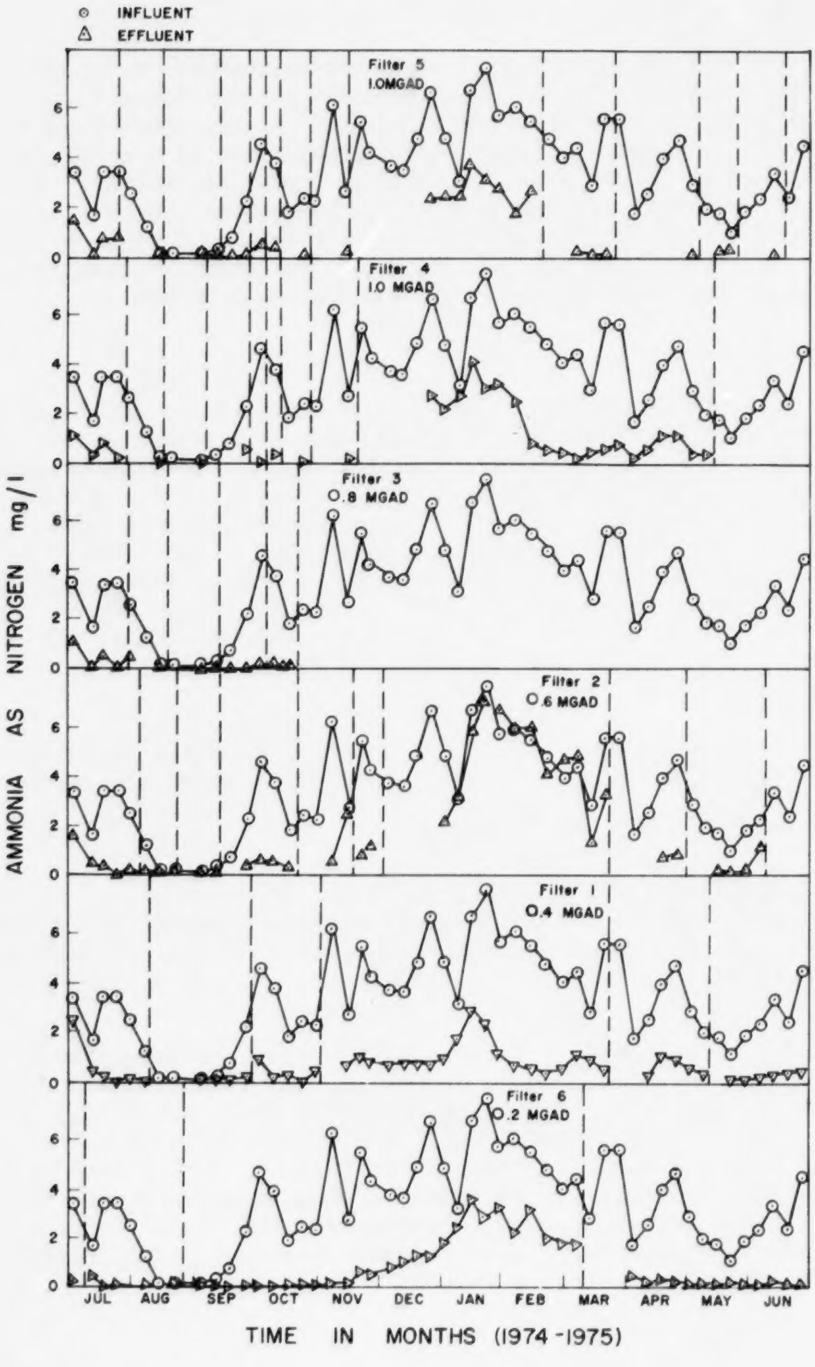


Figure 10. Filter ammonia-nitrogen performance plots separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

Nitrite as Nitrogen (NO_2-N)

Influent and effluent nitrite-nitrogen concentrations are shown in Figure 11. In general, filtered effluent nitrite-nitrogen concentrations are extremely low. The data indicate that nitrite-nitrogen is rapidly converted to nitrate-nitrogen. However, the rate of nitrite-nitrogen conversion to nitrate-nitrogen appears to be related to the hydraulic loading rate (Figure 18). Filters with higher hydraulic loading rates produce an effluent with a higher nitrite-nitrogen concentration. This may be due to the amount of time the water is in contact with the sand filter bed. In general, the higher hydraulic loading rates resulted in less contact time with the sand filter bed.

Nitrate as Nitrogen (NO_3-N)

Influent and effluent nitrate-nitrogen concentrations are shown in Figure 12. Nitrification within each filter yields high concentrations of nitrates when compared to the influent. Overall filter effluent averages ranged from 3.6 (filter number 4) to 4.7 mg/l NO_3-N (filter number 6) while the overall influent average was only 0.1 mg/l NO_3-N. In general, higher loading rates produce lower nitrate concentrations in the effluent (Figure 18). No mass balance of nitrogen could be performed on the results of this study because organic nitrogen was not quantified. deVries (1972) found, however, that nitrification was almost complete and that there was an overall nitrogen loss. Nitrogen removal by bacterial assimilation and denitrification were probably the reasons for the loss.

The anaerobic conditions within filter number 2 during the winter period indicate that nitrification is not significant under anaerobic filter operation.

pH

Figure 13 indicates that influent pH ranged from 7.7 to 9.5 while filter effluent pH ranged from 7.1 to 8.5. In all but one case (filter number 5, January 2, 1975) the filter effluent pH was lower than the influent pH. The filters have a buffering effect on the influent which can be seen in Figure 13.

Temperature

Figure 14 shows temperature variations for influent and effluent waters. Effluent temperatures followed those of the influent very closely. During cold weather operations all effluent average temperatures were slightly lower than influent temperatures. This was probably due to the influent waters thawing frozen ice and sand as it passed through the filter. During warm weather operations the water temperature increased as lagoon effluent passed through the filters. Filter effluent average temperatures increased as hydraulic loading rate increased (Figure 19). This may have been due to increased biological activity within the heavier loaded filters.

Dissolved Oxygen (DO)

Figure 15 illustrates the filter influent and effluent dissolved oxygen concentrations as a function of time. Operation of the intermittent sand filters appeared to aerate the applied wastewater. Aeration of the wastewater may occur

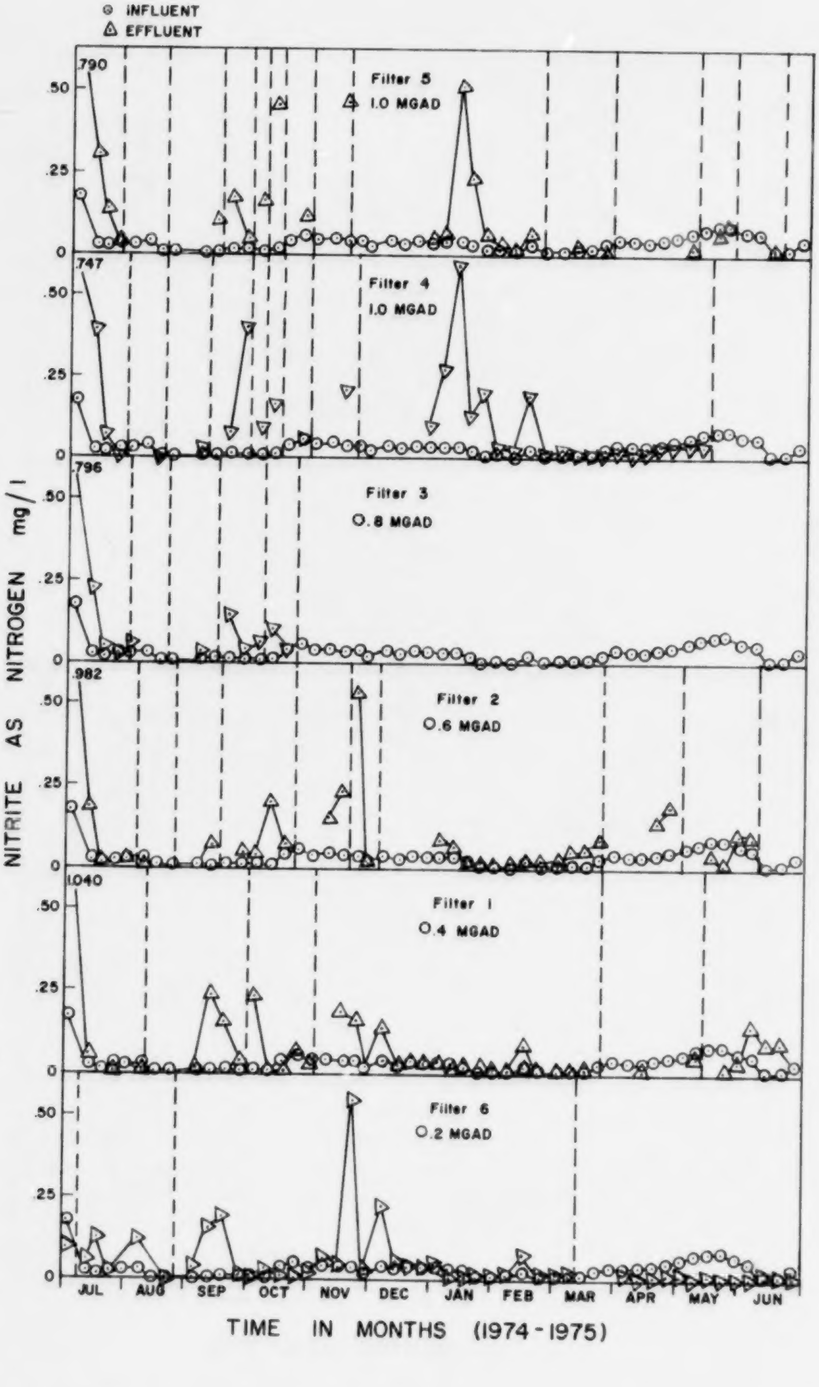


Figure 11. Filter nitrite-nitrogen performance plots separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

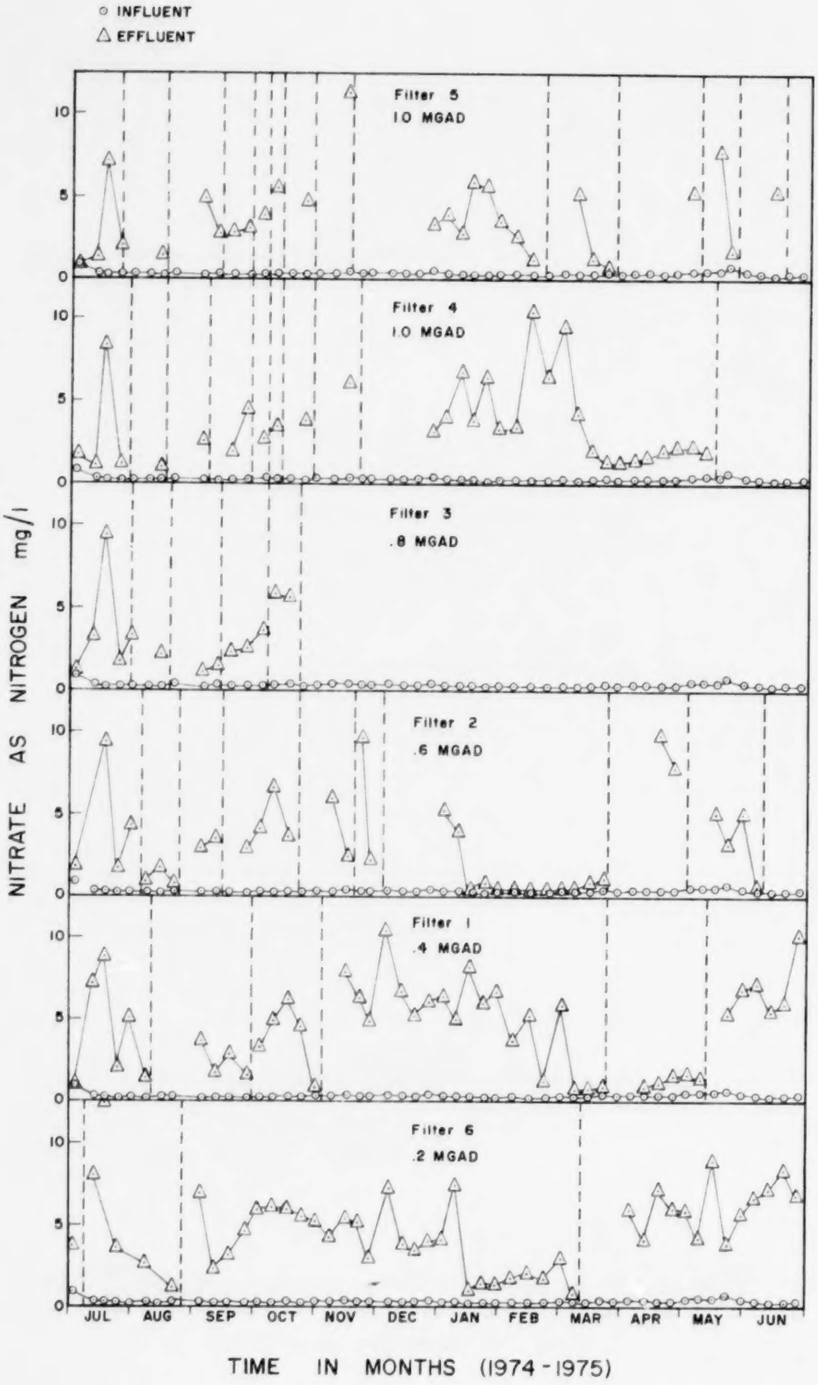


Figure 12. Filter nitrate-nitrogen performance plots separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

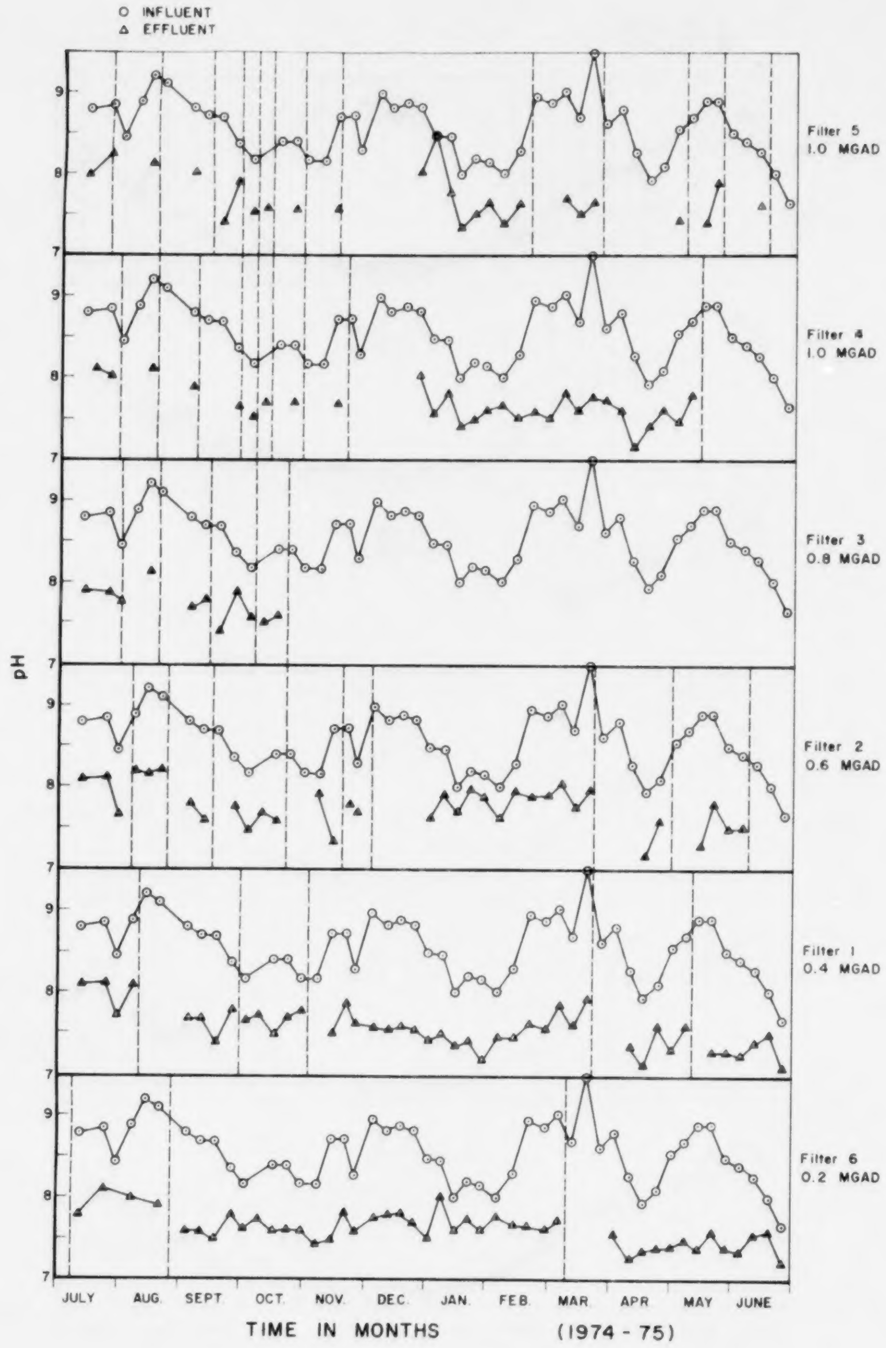


Figure 13. pH values of filter influent and effluent separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

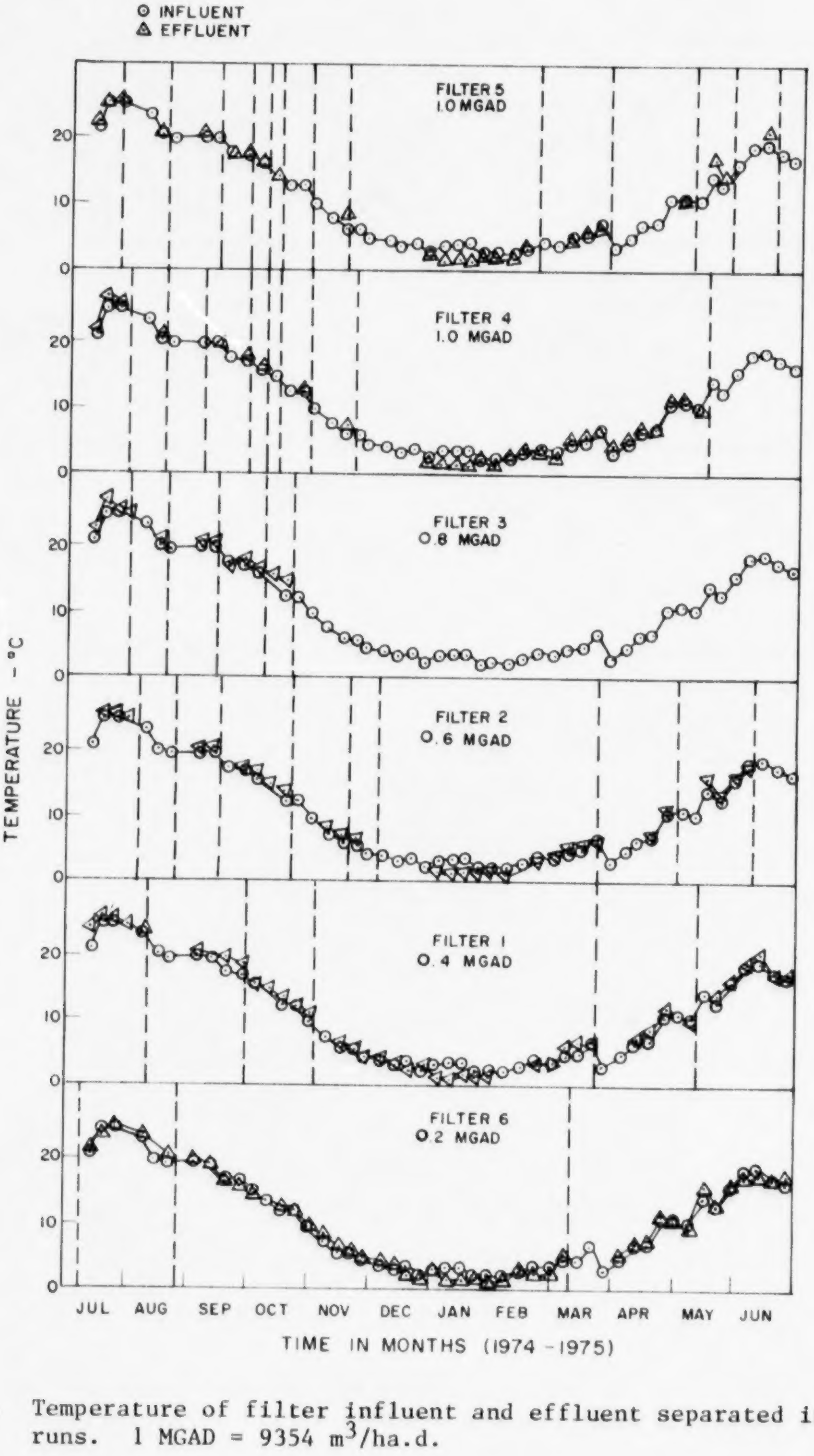


Figure 14. Temperature of filter influent and effluent separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

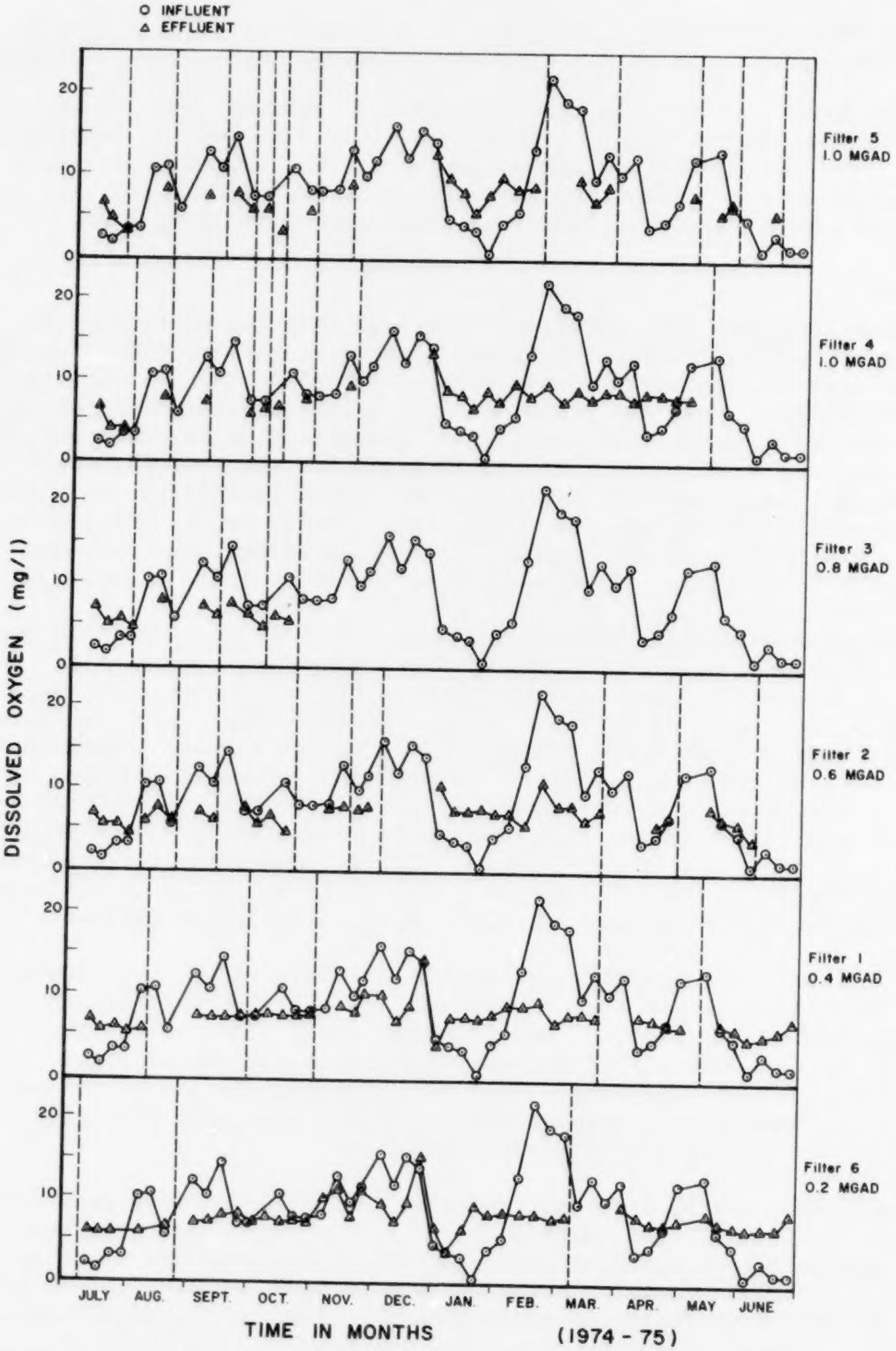


Figure 15. Dissolved oxygen concentrations of filter influent and effluent separated into filter runs. 1 MGAD = 9354 m^3/ha.d.

(i) as the filters are dosed, (ii) as the wastewater percolates through the sand filter bed, or (iii) as the effluent discharges through the underdrain system.

It was found that the dissolved oxygen concentration (DO) increased when the influent was low in DO and decreased when the influent was supersaturated. In general, effluent dissolved oxygen concentrations ranged from 4 to 8 mg/l during warm weather. Effluent DO concentrations were never below 3.3 mg/l. All influent and overall filter effluent averages were above 6 mg/l DO.

Algal Removal

Algal cell counts were performed weekly on influent wastewater and one of the filter effluents. Since each filter plugged at various times during the year the filter effluent cell counts were performed on various filters throughout the experiment. This was performed as a gross quantification of cell removal as well as a qualitative analysis of genus removed (algal genus analysis is found in the next section). Figure 16 indicates the influent algal cell concentration, filter removal efficiency and individual filter run lengths during the study. The filter run length lines in Figure 16, which do not have a definite end point indicate that the particular filter was taken out of service prior to plugging. Thus the filter had no definite filter run length.

Borchardt and O'Melia (1961) found that cell removal efficiency decreased with time to a constant minimum, which ranged from 20 to 40 percent. It is easily seen from the percent removal lines in Figure 16 that cell removal decreases did not occur during this study. However, there are significant differences between Borchardt and O'Melia (1961) and this study. These differences are (i) Borchardt and O'Melia (1961) employed homogeneous algal species and constant cell numbers, (ii) Borchardt and O'Melia (1961) did study wide temperature variations, (iii) the smallest effective size sand used by Borchardt and O'Melia (1961) was 0.316 mm (0.012 in.), and (iv) the hydraulic loading rates employed by Borchardt and O'Melia (1961) varied from 116,930 to 1,169,300 m^3/ha.d (12.5 to 125 MGAD) with tap water instead of lagoon effluent.

The current study found that there was a consistently high removal efficiency for both high and low influent cell counts, but that proportionally greater numbers of algal cells passed through the filters with higher algal cell concentrations. It was also found that algal cell removal efficiency did not decrease to a minimum with time. This could possibly be due to the heterogeneous nature of the algal genera applied as well as the fact that biological degradation was a large part of the filtering mechanism.

A regression analysis was performed on the number of days each filter ran against the total number of cells loaded. It was found that cell numbers were not the determining factor in filter clogging; i.e., the more cells applied, the shorter the run. However, algae species present may be a determining factor. By carefully analyzing algal genera during various algal blooms in the lagoon, it was found that Aphanocapsa sp. was possibly the major cause of short filter runs from August to November of 1974 and Micractinium sp. the possibly major cause of short filter runs from April to May of 1975. This conclusion is very tenuous as bacterial activity, organic loading, nutrient loading, and the aerobic conditions within each filter may also affect filter run length.

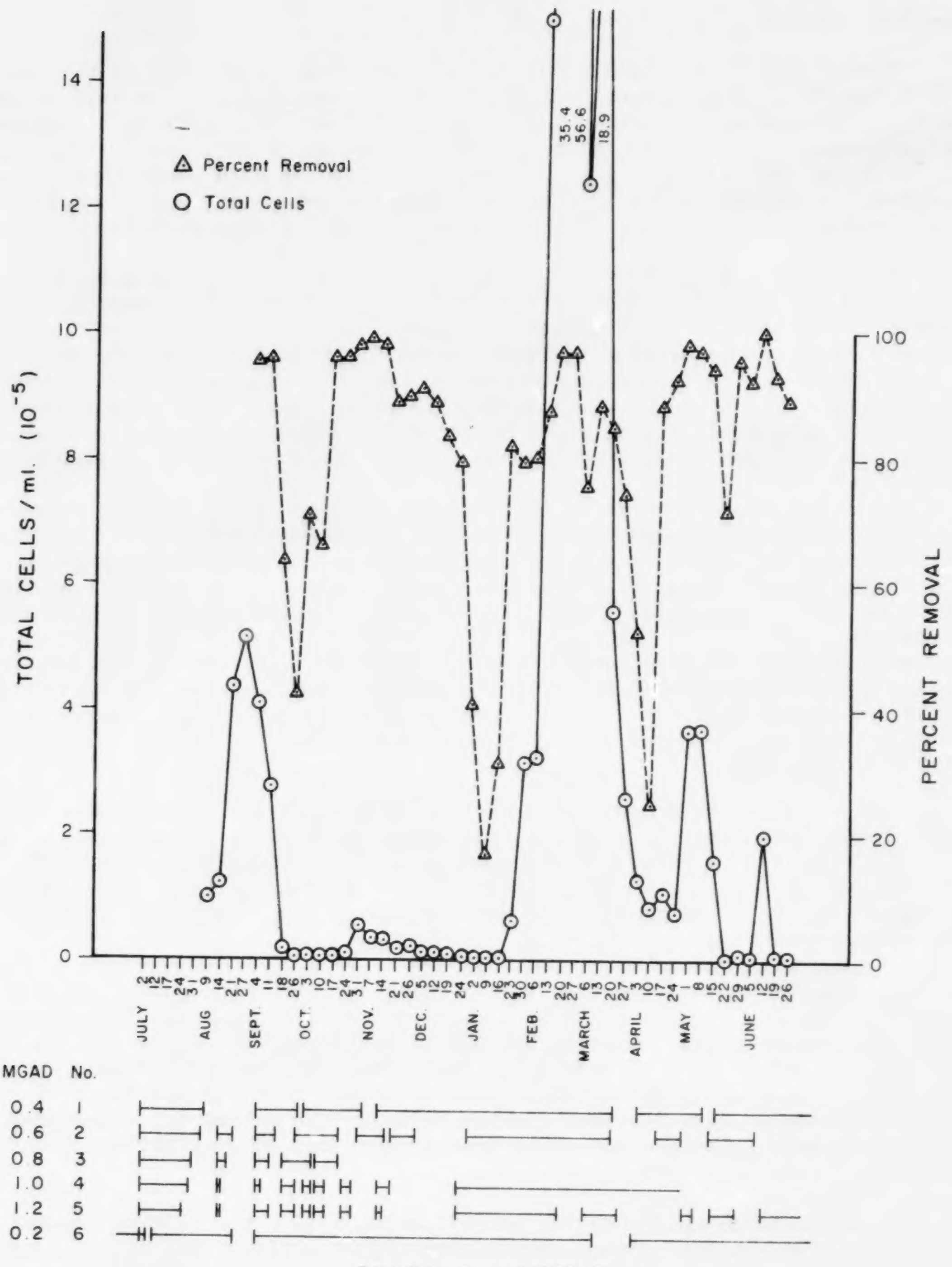


Figure 16. Influent algal cell counts, percent cell removal by filtration and filter run length comparisons. 1 MGAD = 9354 m^3/ha.d.

SEASONAL RESULTS

Parameter average and percent removal bar graphs presented in this section are a summary of the seasonal values given in Appendix A-2. The various seasons are defined as (i) summer (June 26 to September 20), (ii) fall (September 26 to December 19), (iii) winter (December 23 to March 20), and (iv) spring (March 27 to June 19). It should be noted in viewing each graph that cross-hatched bars represent the influent averages for the entire year or season while shaded bars represent effluent averages for the same periods.

Plain bars signify that data were available and values calculated, but the values obtained may not represent the season accurately. For example, filter number 3 (7484 m^3/ha.d or 0.8 MGAD) was taken out of service in October and is biased toward warmer weather. Filter number 2 (5613 m^3/ha.d or 0.6 MGAD) was allowed to go anaerobic during the winter months which drastically affected its performance. Filter number 4 (9354 m^3/ha.d or 1.0 MGAD) developed a crack sometime during early spring which effected the effluent from one of the sampling parts (i.e. allowed raw influent water to drain from one of the sampling ports).

It should also be noted in interpreting results of the overall, seasonal average and percent removal bar graphs that the two may not appear to coincide. In some cases the influent average was lower than the effluent average and yet a positive percent removal is graphed. This is because the influent averages are a total of every sample day during the season while percent removal calculations are based on only those days when the filter was in operation during the season. Removal efficiencies would be highly biased if the influent for an entire season were used rather than the influent concentration actually being applied to the filter.

Parameter Averages

Figures 17 to 19 present a comparison of the overall and seasonal filter performance with respect to various parameters as well as a comparison of each individual filter performance on a seasonal basis. The effect of hydraulic loading rate on seasonal filter performance is also illustrated. The overall averages represent the mean of all data collected for each filter throughout the entire study.

In general both the seasonal and overall effluent average concentrations of BOD_5, COD, SS, VSS, NH_3-N, NO_2-N, and NO_3-N are independent of the average influent concentration. That is average effluent concentrations of BOD_5, COD, SS, VSS, and NH_3-N were substantially lower than the average influent concentration. However, average effluent concentrations of NO_2-N and NO_3-N were generally greater than influent average values. The values for total phosphorus, ortho-phosphorus, temperature, dissolved oxygen, and pH are similar to influent values.

As illustrated by Figure 18, nitrification within the filters appears to fluctuate on a seasonal basis. Relatively higher effluent ammonia-nitrogen values were obtained during the winter with correspondingly lower nitrate-nitrogen values. This is probably a result of lower winter temperatures which tend to decrease biological nitrification. In general, the filter performance with respect to the other parameters is not affected by seasonal variations.

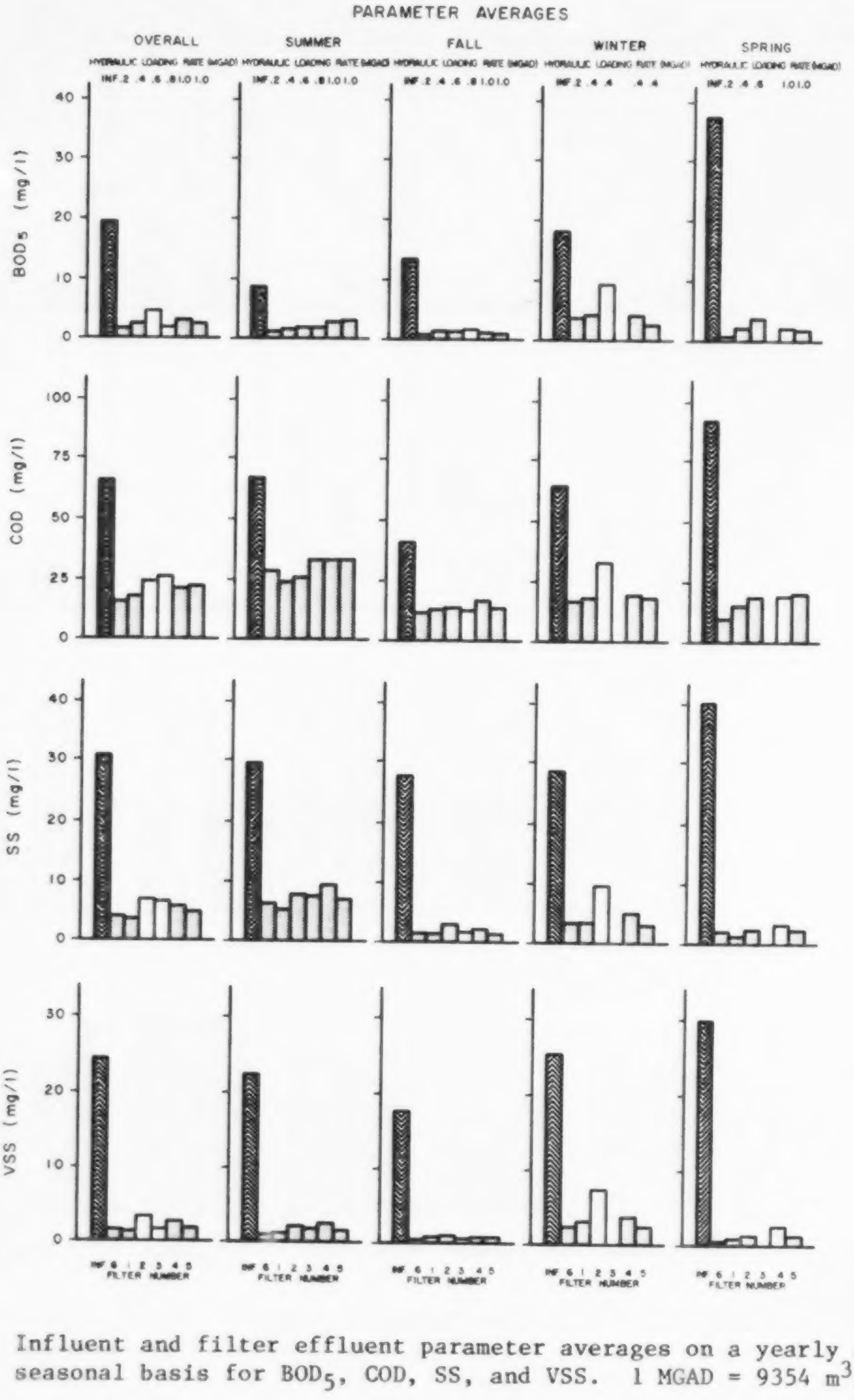


Figure 17. Influent and filter effluent parameter averages on a yearly and seasonal basis for BOD_5, COD, SS, and VSS. 1 MGAD = 9354 m^3/ha.d.

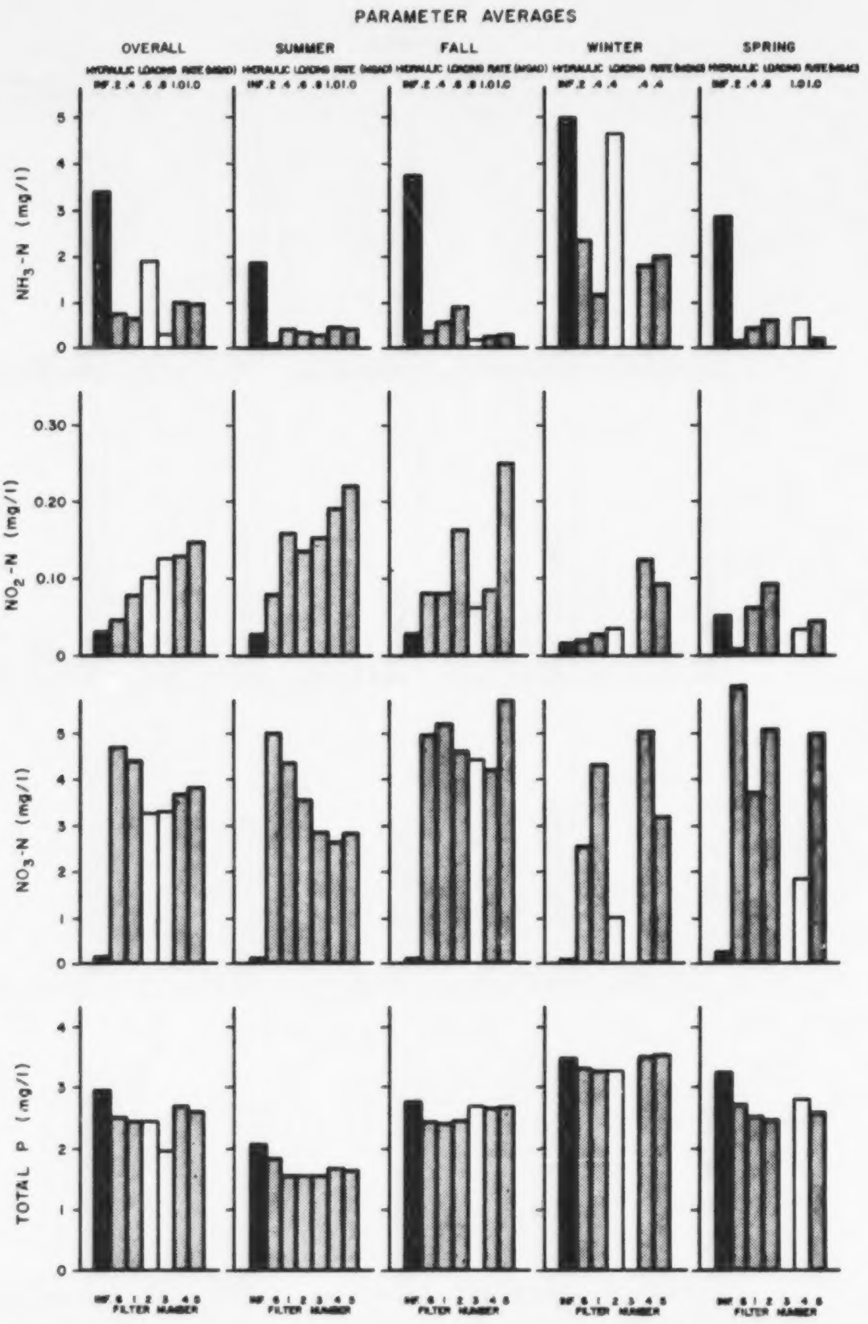


Figure 18. Influent and filter effluent parameter averages on a yearly and seasonal basis for NH_3-N, NO_2-N, NO_3-N, and Total Phosphorus. 1 MGAD = 9354 m^3/ha.d.

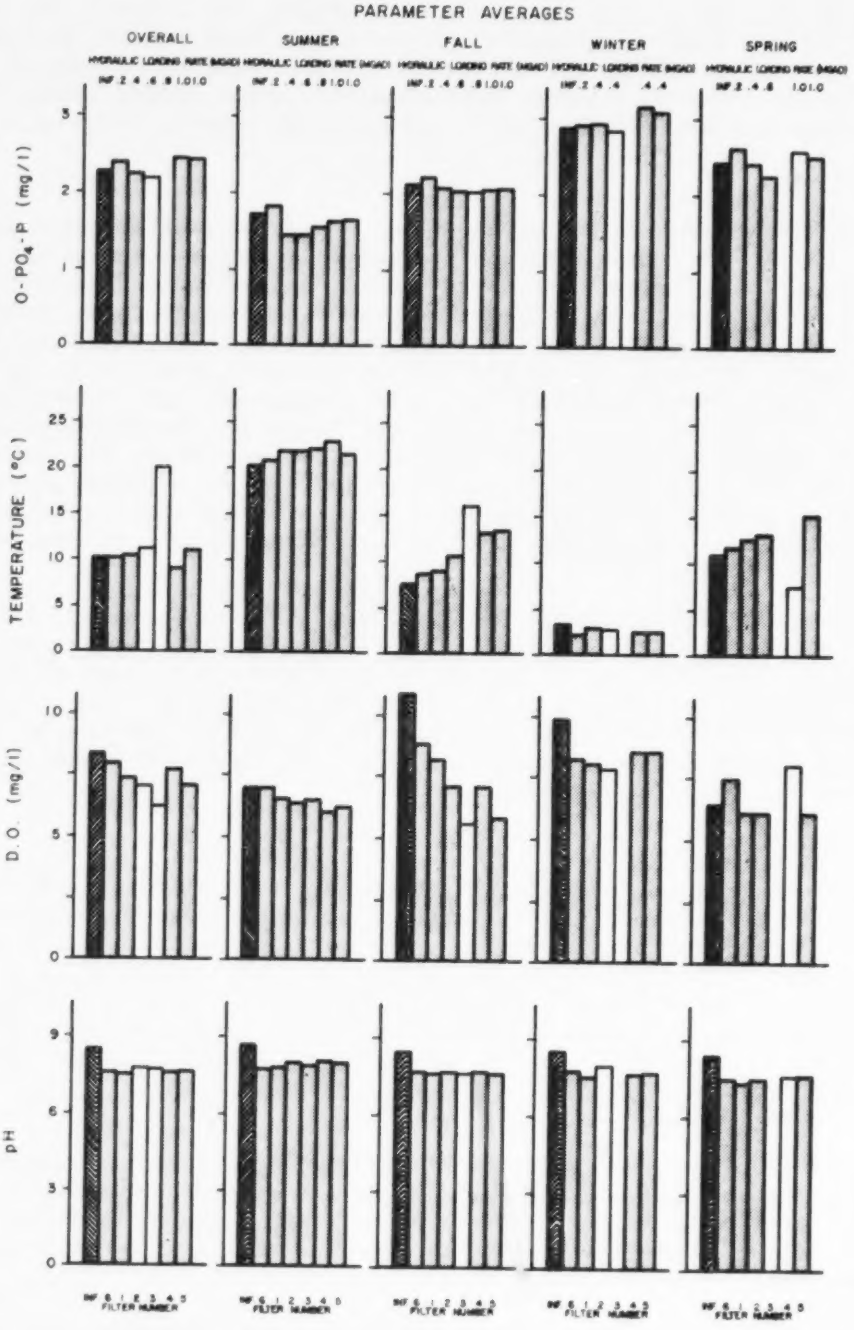


Figure 19. Influent and filter effluent parameter averages on a yearly and seasonal basis for O-PO_4-P, Temp., DO, and pH. 1 MGAD = 9354 m^3/ha.d.

Although the effluent concentrations are relatively low and thus a direct comparison between various hydraulic loading rates is difficult, it does appear that lower hydraulic loading rates produce a higher quality effluent. This is particularly evident with regards to biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) removal. Also greater nitrification occurs at lower hydraulic loading rates.

Percent Removals

Percent removal values for seven of the twelve parameters measured are graphed on Figure 20. These indicate that removal does not decrease with time; however removal is dependent on temperature and hydraulic loading rates for certain parameters. However, only general trends should be taken from these graphs. It could be observed that the middle hydraulic loading rates are the least efficient. However, all of the filters were not loaded with the same wastewater. The heavier loaded filters were plugged and out of service much more of the time than were the lightly loaded filters. The heavier loaded filters did not function when influent concentrations were high, but did operate for longer periods when influent values were low. Thus, a direct comparison of the percent removal efficiency between filters is not valid. The percentages obtained are biased by the number and absolute value of the effluent samples collected.

Figure 20 does indicate the effects of the start-up period on BOD_5, COD, SS, Total P and $O\text{-}PO_4\text{-}P$. A relatively low removal efficiency was achieved on all filters for BOD_5, COD and SS during the initial summer loading period. The removal of Total P and $O\text{-}PO_4\text{-}P$ during this same time was relatively high. This was probably due to both adsorption of phosphorus on the sand grains and assimilation of phosphorus into the biological mass. Phosphorus removal will be discussed further under filter performance.

Algae Present

Algae identification and quantification were performed for influent and effluent waters from August 6, 1973, through June 26, 1974. During this 11 month period 23 separate algae genera were identified. Every genus showed large variations in numbers of cells counted from one sample day to another. Because of these blooms and die-offs every genus also showed large variations in filter removal efficiencies. Some of the genera (Oscillatoria sp. and Microcystis sp.) were present during the entire sampling period, others (Schroederia sp., Gloeocapsa sp., Closterium sp. and Aphanocapsa sp.) showed seasonal blooming patterns.

The variations in the algal population are illustrated in Figures 21 through 24. A simple alphabetical listing with a crude description of each genus was thought to be of more value than a formal grouping by Phyla and Order. The most prevalent genera are graphed to show influent cell count variations. The ordinate scale changes on each graph.

It was noted earlier that cell numbers had little effect on the length of filter runs, but that algae genus present may affect the length of filter runs. Cell descriptions and influent cell counts indicate the effect any one genus may have had on a particular filter run length. Numerical values listed on Figures 21 to 24 indicate the relative importance of each genus, and filter removal efficiencies for each season.

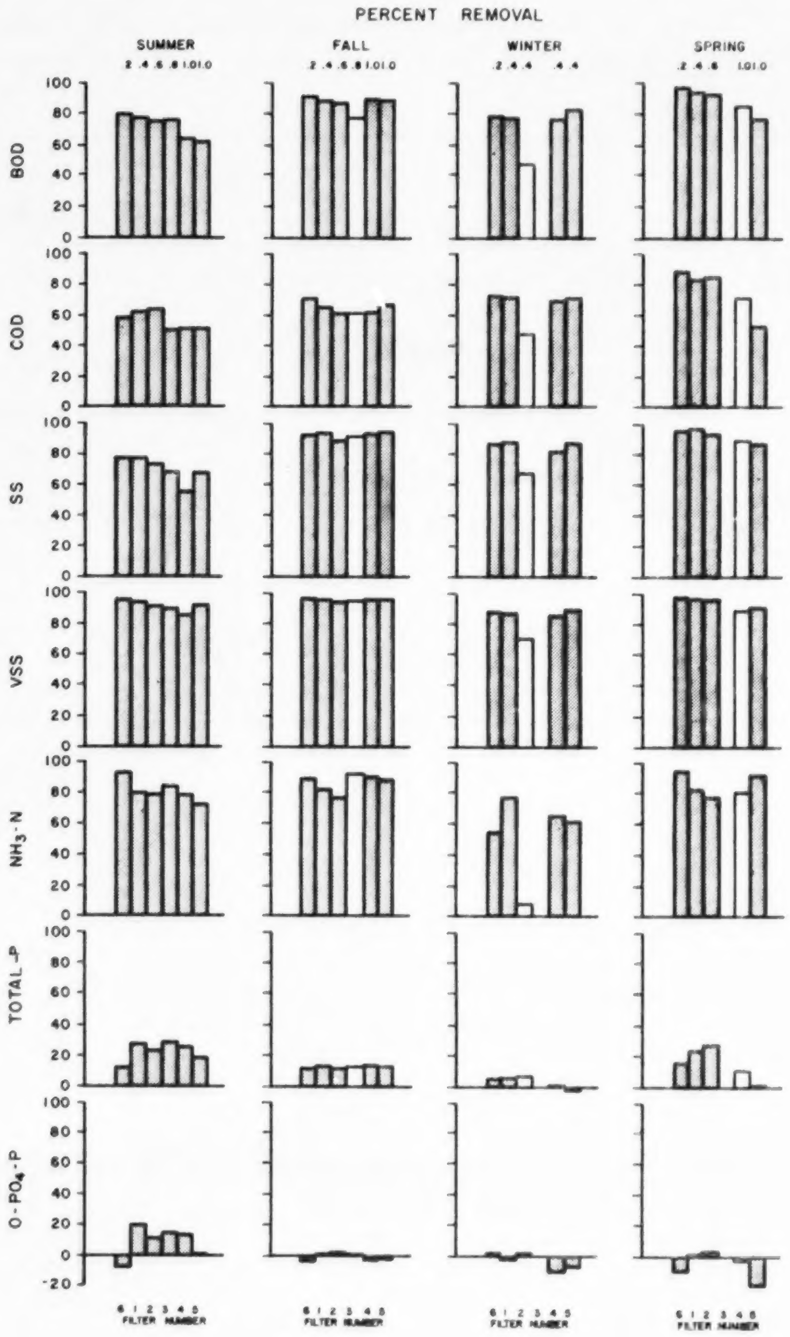
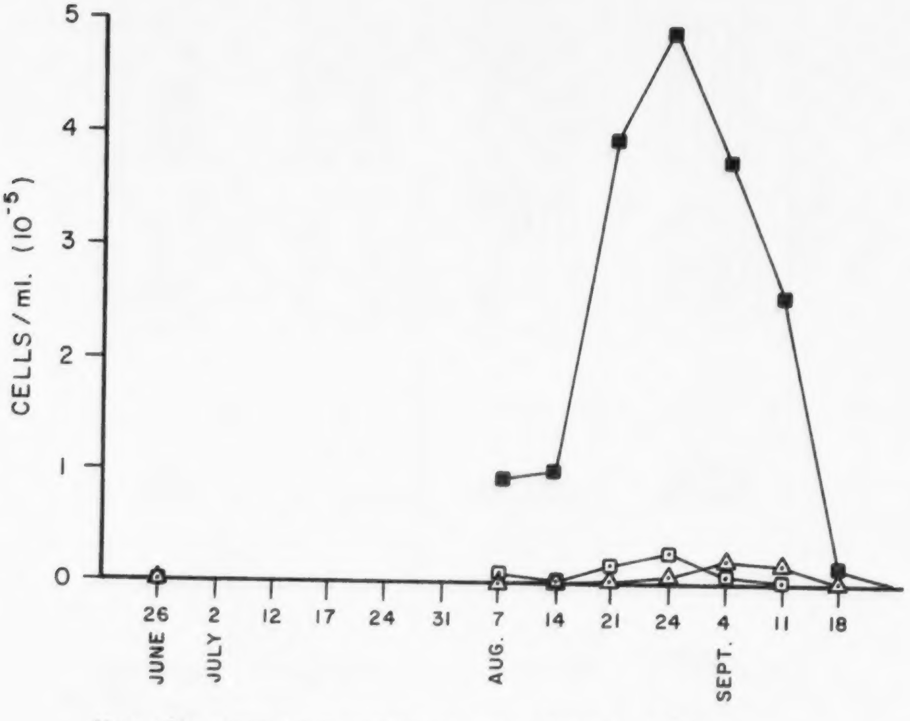


Figure 20. Seasonal percent removals for selected parameters. 1 MGAD = 9354 m^3/ha.d.

SUMMER--June 26 - September 20

Average Influent (Cells/ml): 213,922
Average Effluent (Cells/ml): 10,060
Percent Removal: 94
Average Zooplankton (No./l): 292

Genus	Description	Ave. Count (cells/ml)	No. Weeks Counted	Seasonal % Removal	% of Total Cells Counted	Genus Graphed
Aphanocapsa sp. (Euplanktonic)	Small cells regularly spaced in gelatinous sheath.	220,802	8	94	92	■
Chlamydomonas sp. (Palmelloid)	Without Flagella, in mucilage and extensive gelatinous masses.	1,395	5	100	0	
Chlorella	Small, oval or spherical cell.	274	1	25	0	
Euglenoids	Solitary, mottle, one or two flagella.	150	3	–	0	
Microcystis sp.	Cells arranged in gelatinous sheath.	1,161	7	88	0	
Navicula sp.	Cigar shaped	8,935	8	85	4	□
Oscillatoria sp.	No sheath, thread-like structure, filamentous.	6,499	8	96	3	△
Pediastrum sp.	Circular plates.	1,828	2	100	0	
Schroederia sp.	Long with stout spine.	326	7	100	0	
Unknown Pennate	Feather-like.	1,949	7	86	1	



Note : No algae data was taken through July, 1974

Figure 21. Summary of influent algae cells identified during the summer and a graph of the major genera blooms.

FALL--September 26 - December 19

Average Influent (Cells/ml): 19,684
Average Effluent (Cells/ml): 1,441
Percent Removal: 93
Average Zooplankton (No./l): 44

Genus	Description	Ave. Count (cells/ml)	No. Weeks Counted	Seasonal % Removal	% of Total Cells Counted	Genus Graphed
Ankistrodesmus c.	Loosely clustered needles.	832	7	95	2	
Aphanocapsa sp. (Euplanktonic)	Small cells regularly spaced in gelatinous sheath.	1,099	7	43	3	■
Closterium sp.	Two semi-cells, crescent shaped.	1,525	6	80	4	▼
Cryptomonas sp.	Flagellate, oval shaped, fast moving, sparse.	1,003	1	79	0	
Euglenoids	Solitary, motile, one or two flagella.	363	13	82	2	
Gloeocapsa sp.	Concentric layers of mucilage, gelatinous masses.	8,278	2	90	6	○
Microcystis sp.	Cells arranged in gelatinous sheath.	1,186	13	91	6	▽
Navicula sp.	Cigar shaped.	130	6	47	0	
Oscillatoria sp.	No sheath, thread-like structure, filamentous.	3,230	13	96	16	△
Pediastrum sp.	Circular plates.	1,215	3	100	1	
Phacotus sp.	Egg shaped, granular with flagella.	14,265	10	96	56	●
Planktosphaeria sp.	Spherical cells in mucilaginous sheath (thin).	1,188	1	100	0	
Schroederia sp.	Long, stout spine.	257	7	99	1	
Stephanodiscus sp.	Large, drum shaped.	244	4	96	0	
Unknown Pennate	Feather-like.	26	3	-18	0	

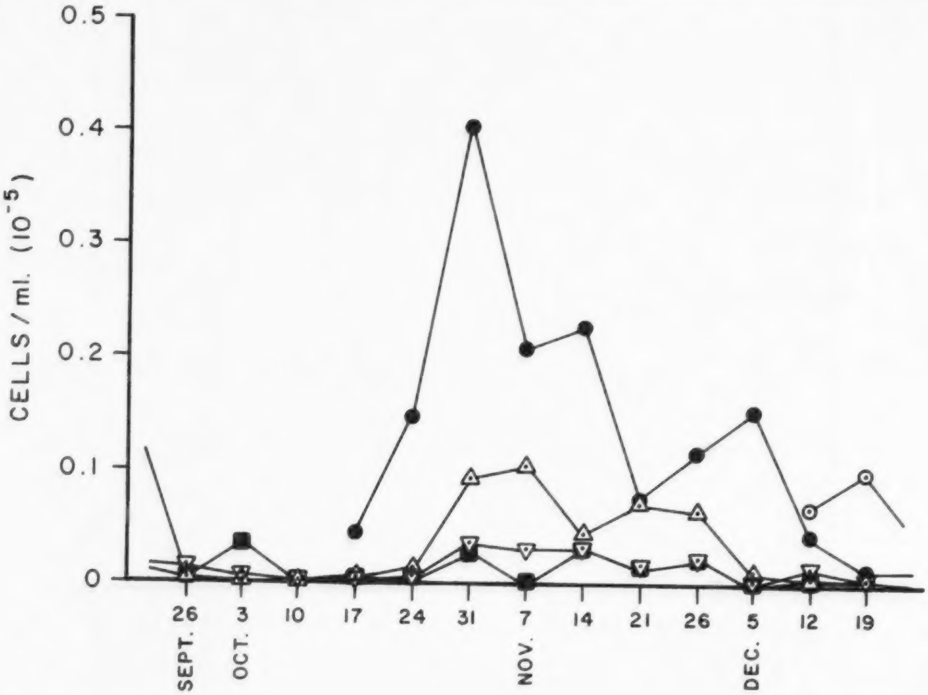


Figure 22. Summary of algae cells identified during the fall and a graph of the major genera blooms.

WINTER--December 26 - March 20

Average Influent (Cells/ml): 1,161,188
Average Effluent (Cells/ml): 93,856
Percent Removal: 92
Average Zooplankton (No./l): 108

Genus	Description	Ave. Count (cells/ml)	No. Weeks Counted	Seasonal % Removal	% of Total Cells Counted	Genus Graphed
Chlamydomonas sp. (Palmelloid)	Without flagella, extensive gelatinous masses.	2,458	8	81	0	
Closterium sp.	Two semi-cells, crescent shaped.	43	2	11	0	
Euglenoids	Solitary, motile, one or two flagella.	183	7	75	0	
Gloeocapsa sp.	Concentric layers of mucilage, gelatinous masses.	1,096,334	13	92	94	○
Merismopedia sp.	Cells in rectangular plate, colonies in sheets.	5,588	2	92	0	
Microcystis sp.	Cells arranged in gelatinous sheath.	4,537	13	91	0	
Navicula sp.	Cigar shaped.	85	2	62	0	
Oscillatoria sp.	No sheath, thread-like structure, filamentous.	546	10	61	0	
Phacotus sp.	Egg shaped, granular, with flagella.	1,621	10	81	0	

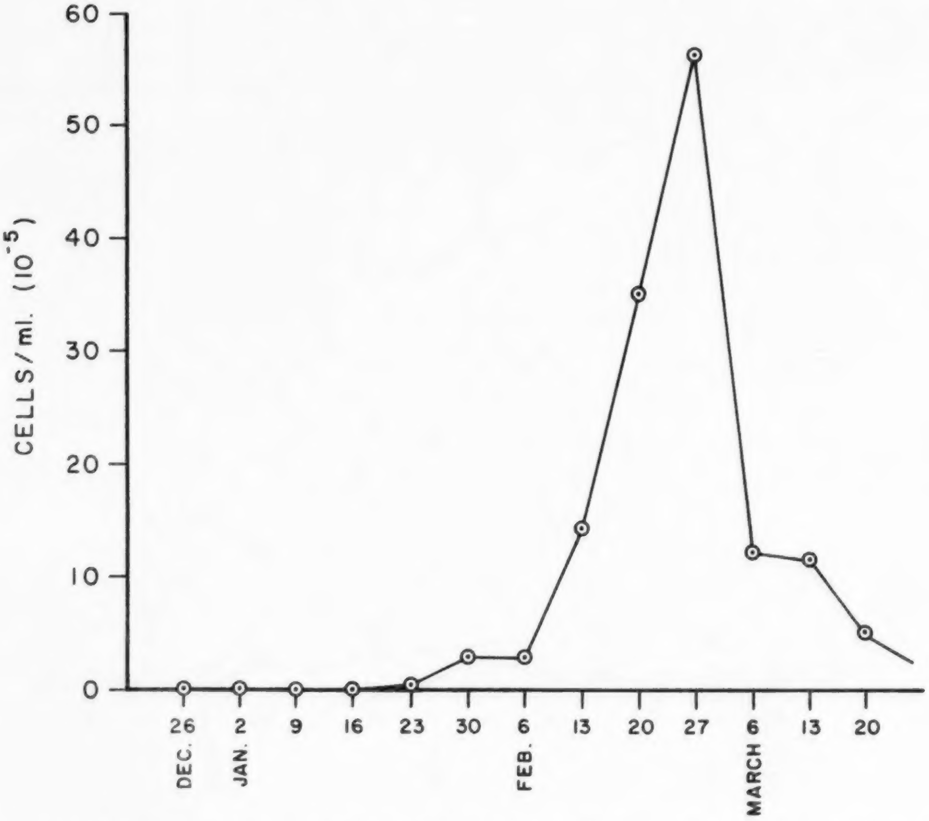


Figure 23. Summary of algae cells identified during the winter and a graph of the major genus bloom.

SPRING--March 27 - June 19

Average Influent (Cells/ml): 136,483
Average Effluent (Cells/ml): 18,704
Percent Removal: 86
Average Zooplankton (No./l): 1,148

Genus	Description	Ave. Count (cells/ml)	No. Weeks Counted	Seasonal % Removal	% of Total Cells Counted	Genus Graphed
Ankistrodesmus c.	Loosely clustered needles.	99	2	80	0	
Ankyea	Curved, fusiform cell with spine at one end.	392	1	100	0	
Chlamydomonas sp. (Palmelloid)	Without flagella, extensive gelatinous masses.	9,658	7	82	4	
Chlorella, sp.	Small, oval or spherical, single or bunched.	4,555	4	97	1	
Cryptomonas sp.	Flagellate, oval shaped, fast moving, sparse.	78	1	100	0	
Euglenoids	Solitary, motile, one or two flagella.	226	2	87	0	
Gloeocapsa sp.	Concentric layers of mucilage, gelatinous masses.	85,470	10	78	48	○
Merismopedia sp.	Cells in rectangular plates, colonies in sheet.	3,038	2	90	0	
Micractinium sp.	Clusters of four cells in tetraheoral, long spines.	57,039	7	96	23	◇
Micrasterias sp.	Flat, disclike shape, jagged and rough.	10,192	1	32	1	
Microcystis sp.	Cells arranged in gelatinous sheath.	9,376	13	92	7	▽
Navicula sp.	Cigar shaped	4,391	5	97	1	
Oscillatoria sp.	No sheath, thread-like structure, filamentous.	835	5	74	0	
Pediastrum sp.	Circular plates.	12,347	6	100	4	
Phacotus sp.	Egg shaped, granular cell, with flagella.	490	2	80	0	
Scenedesmus sp.	Oval, fusiform or crescent, in rows of four.	157	1	100	0	
Stephanodiscus sp.	Large, drum shaped.	48,491	4	98	11	▲

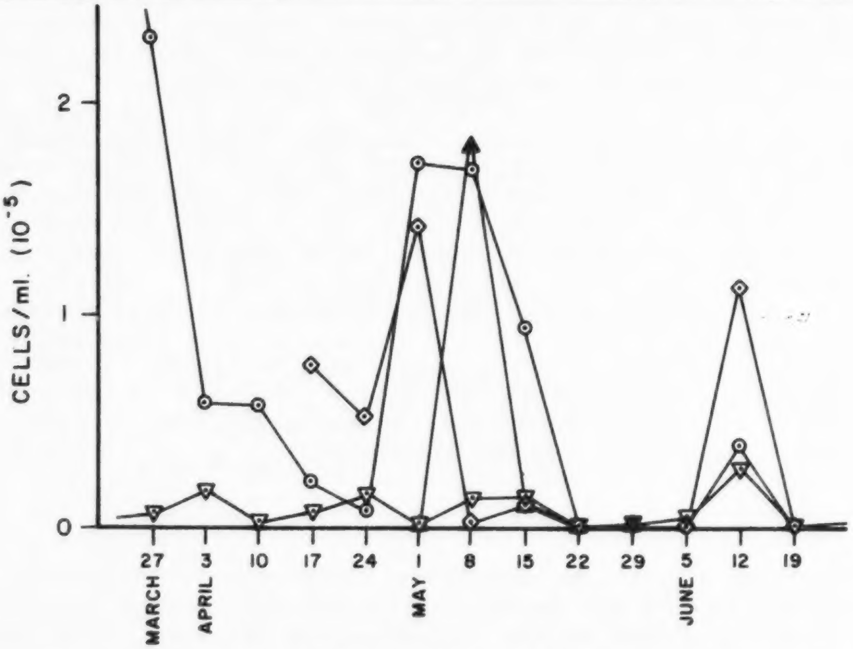


Figure 24. Summary of algae cells identified during the spring and a graph of the major genera blooms.

There are both similarities and differences in comparing these removal results with those reported in the literature (Borchardt and O'Melia, 1961; Folkman and Wachs, 1970; Ives, 1961; Marshall and Middlebrooks, 1974). Borchardt and O'Melia (1961) found a 28 - 45 percent removal for Anaebaena, 2 - 33 percent removal for Ankistrodesmus and 6 - 36 percent removal for Scenedesmus while Ives (1961) found a 97 percent removal for Chlorella and a 100 percent removal for Scenedesmus. On a weekly basis this study found a 69 - 100 percent removal for Ankistrodesmus c., a -280 percent to 100 percent removal for Chlorella sp. and 100 percent (one time reading) removal for Scenedesmus sp. On a seasonal basis the removal efficiencies were 80 - 95 percent, 25 - 97 percent and 100 percent (one time reading) respectively. Some reasons have already been given to account for these differences. On the basis of the findings in this study, the intermittent sand filter does achieve a significant removal of many algae species.

An attempt was made to correlate removal performance on a seasonal basis with genus and algal cell concentration using a modified Bray-Curtis Similarity Index. The index itself compares various taxa and their relative abundance at two stations over time. It numerically indicates the relative condition of the two stations and may compare a known, unpolluted system to one which may be polluted. An index of 1.0 indicates the two stations are completely similar while an index of 0.0 indicates complete dissimilarity. Wilhm (1967) gives the equations

$$P = \bar{c}\, F^{1/2} \quad \text{and} \quad c = \frac{2\,(\Sigma\text{Pmin})}{\Sigma\text{Pi} + \Sigma\text{Pj}}$$

where c is the similarity index, $\bar{c}$ is the average number of organisms of a given taxanomic group and F is the frequency that the group may be present over time. P is the prominence value of any given taxanomic group and ΣPi or ΣPj is the summation of all the prominence values at station i or station j. ΣPmin is the lower of the two prominence values at station i or station j.

Calculating the similarity index c for summer, fall, winter and spring resulted in values of 0.12, 0.15, 0.15 and 0.22 respectively. These values indicate that: 1) influent and effluent cell counts and genera are dissimilar (the filters do remove algae), 2) all algae are not removed with the same efficiency, 3) seasonal variations in removal efficiency occur (different genera bloomed during each season), and 4) there may be a trend toward less efficient algal removal over a long period of time. There are enough variables present to invalidate the last conclusion and only a study of several years could verify it; as the upward trend toward similarity may only be cyclic. It may be a one-time phenomena caused by the specific genera present or it may actually be an aging process. All of the other data, including total cell removal efficiencies, tend to discredit the last conclusion.

SUMMER/WINTER OPERATIONS

The difference in operating procedures, filter removal performance and the length of time the filters ran before plugging all pointed to a need to analyze the available data on a warm weather versus cold weather basis. A discussion comparing the warm weather performance of the filters with the cold weather performance is presented in this section.

Warm Weather

Data collected during summer, fall and spring have been grouped and averaged in an effort to evaluate filter performance under favorable conditions over a long period of time. This was done to determine the effect of loading rate on effluent quality and establish expected run lengths at various loading rates. Averages from the data collected during warm weather for the 12 parameters measured are presented in Table 5.

As was shown in the literature and in the previous section, BOD_5 increases slightly with increased loading rate. COD, SS, VSS, NH_3-N, NO_2-N, pH and temperature also increase with increased loading rate. Suspended solids increases may be objectionable, but it should be recognized that the initial start-up ‘‘wash-out’’ period is included in these averages. The parameters of Total-P, O-PO_4-P, NO_3-N and DO generally decrease with increased loading rate. The decrease in DO during this warm weather period may be one limiting factor in utilizing high hydraulic loading rates.

The warm weather averages presented in Table 5 indicate that effluent quality decreases with increased loading rates. However, even the worst average values are extremely low when compared to conventional waste treatment processes.

The average warm weather filter run length for each hydraulic loading rate is given in Table 6. As expected and reported in the literature (Folkman and Wachs, 1970), the length of filter run is directly related to the hydraulic loading rate. Average filter run lengths varied from 8.1 days on a raked filter loaded at 9354 m^3/ha.d (1.0 MGAD) to 64 days on a scraped filter loaded at 1871 m^3/ha.d (0.2 MGAD).

Individual run lengths varied from 26 days in early summer to 3 days during heavy algal loading and hot weather for the 9354 m^3/ha.d (1.0 MGAD) loaded filter. For the 1871 m^3/ha.d (0.2 MGAD) loaded filter, run lengths ranged from 42 to 85 days over the same period of time. Two mechanisms, both triggered by the growth of algae on the filters, cause this wide variance. The time of day at which the filters are loaded effects the length of filter run. Filters which are loaded early in the morning and have influent standing on them throughout the daylight period may experience algal growth in the liquid above the sand filter bed. An experiment was conducted in which 15 cm (6 inch) diameter plexiglass columns were filled with filter influent and placed on the filter surface. The bottoms of the columns were sealed to prevent concentration of the algae as the water percolated through the sand and the water level in the column was held at the same level as the water on the filter by removing water from the column every hour. The experiment was conducted with three columns which permitted light penetration (light columns) and three control columns which were darkened (dark columns) to prevent any light penetration. The columns were gently stirred prior to each sample collection. The suspended solids concentration and the volatile suspended solids concentration of the columns were monitored with time.

The results are recorded in Table 7 and shown graphically in Figure 25. The water remained on the surface of the filter for over 12 hours after loading

TABLE 5. AVERAGE OF SAMPLES COLLECTED DURING THE SUMMER, FALL, AND SPRING EXPERIMENTAL PERIODS

Loading Rate in MGAD	BOD_5 mg/l	COD mg/l	Sus-pended Solids mg/l	Volatile Sus-pended Solids mg/l	Total Phos-phorus mg/l	Ortho-Phos-phate mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	pH	Temp. °C	Dis-solved Oxygen mg/l
Influent	19.3	66.9	31.7	24.2	2.8	2.1	2.9	<0.1	0.2	8.6	12.7	8.0
0.2	1.3	16.1	4.0	0.7	2.4	2.2	0.2	0.1	5.3	7.6	13.1	7.9
0.4	1.9	17.8	3.2	0.9	2.2	2.0	0.5	0.1	4.5	7.6	14.0	7.1
0.6	2.3	20.0	5.9	1.7	2.1	1.9	0.6	0.1	4.3	7.7	15.9	6.5
0.8	1.9	27.0	6.7	1.7	1.9	1.7	0.3	0.1	3.3	7.7	20.2	6.2
1.0 (scraped)	2.3	23.4	6.3	2.2	2.4	2.1	0.5	0.1	2.7	7.7	13.7	7.1
1.0 (raked)	2.3	24.7	5.2	1.3	2.2	2.0	0.3	0.2	4.2	7.7	17.4	6.1

1 MGAD = 9354 m^3/hectare-day.

TABLE 6. AVERAGE LENGTH OF FILTER RUN FOR SUMMER, FALL, SPRING

Filter No.	Hydraulic Loading Rate (MGAD)	Length of Filter Run (Days)
6	0.2 (scraped)	64+
1	0.4 (scraped)	33+
2	0.6 (scraped)	18
3	0.8 (scraped)	15
4	1.0 (scraped)	8.4
5	1.0 (raked)	8.1

1 MGAD = 9354 m^3/hectare-day.

and at the end of the daylight period approximately 0.3 meters (1 foot) of influent water remained on the filter surface. The suspended solids concentration had increased from 77 mg/l at one hour after loading to 222 mg/l at 12 hours after loading. The average suspended solids concentration in the light cylinders over the 12 hour period was 112 mg/l while the average for the dark cylinders during the same period was 75 mg/l. This indicates that the average algae concentration filtered may have been 45 percent greater than the influent measurements indicate. Thus, the filter performance data presented in this report may be extremely conservative.

As shown by Figure 25 and Table 7, the increase in the volatile suspended solids concentration in the liquid standing on the filter during daylight hours is similar to the increase in suspended solids concentration. The volatile suspended solids concentration increased from 56 mg/l at one hour after loading the filter to 109 mg/l at 12 hours after loading the filter. This represents an increase in volatile suspended solids concentration of 97 percent, further indicating the conservative nature of the performance data presented in this report.

The second mechanism limiting filter run length deals with the rise in pH as algae grow and utilize carbon dioxide (CO_2) in the standing water above the sand filter bed. Before pH levels rise above 10 the carbonate ion concentration exceeds its solubility product and calcium carbonate precipitates out (Sawyer and McCarty, 1967). This precipitate bonds the sand particles together in a ''plaster.'' The top 2.5 to 5 cm (1 - 2 in.) of sand then become impermeable. No extensive tests were run to determine the relative plugging action of this hard surface layer, but the same phenomena seems to be described by Holmes (1945). Also, Avnimelech and Nevo (1964) found that this cementing of particles together was related to polyuronide concentrations. This suggests that the hard surface layer which forms on top of the filter (apart from the ''schmutzdecke'') may be a combination of several factors.

TABLE 7. ANALYSIS OF THE INFLUENT LEFT STANDING ABOVE THE FILTERS AFTER LOADING SHOWING ALGAL GROWTH ON FILTERS WITH TIME

Time in Hours	Light Cylinders[a]		Dark Cylinders[a]	
	Suspended Solids (mg/1)	Volatile Suspended Solids (mg/1)	Suspended Solids (mg/1)	Volitile Suspended Solids (mg/1)
1.0	77.1	55.3	75.2	50.0
2.3	81.3	56.3	81.4	55.4
3.6	92.9	62.3	77.4	50.6
5.0	90.0	63.2	73.6	49.2
6.0	93.3	67.0	73.1	53.2
8.0	102.0	74.9	69.2	49.2
10.0	164.0	80.5	68.9	48.1
12.0	222.4	109.0	78.9	52.2
Average	111.6	71.1	74.7	51.0

[a] Average of three columns.

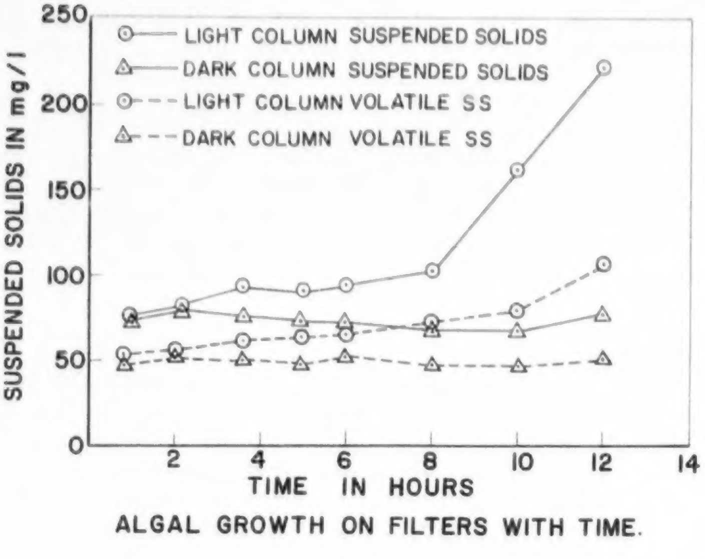


Figure 25. Plot showing algal growth in the standing water above the filters with time.

These results indicate that it may be possible to increase the length of filter run by either loading the filters in the evening or by covering the filters to prevent photosynthesis.

Winter Period

The winter experimental period was conducted under fairly harsh climatic conditions. Ambient air temperature dropped to below -10°F (-23.3°C) for several consecutive days on several occasions. Ice sheets formed on the top of each filter. In many periods when the ice sheets had melted or sublimated the sand surface was frozen solid. Such was the experience of this project.

All of the data collected during the winter experimental period have been averaged over the winter season and these average values are reported in Table 8. The number of individual data points averaged depends on the length of the particular filter run. However, in no case were fewer than three data points used to obtain an average value. Filters number 6, 1, and 4 (control, furrowed, and staked, respectively) all performed satisfactorily. There were minor variations among them, but each produced high quality effluents. When the values in Table 8 are compared to those in Table 7. It can be seen, though, that overall effluent quality dropped below that of the warm weather period.

The winter averages for filter number 2 show a marked difference from the other filters. Anaerobic conditions caused by a constant head on the filter greatly reduced its removal capacity. As can be seen, BOD_5, COD, SS, VSS, NH_3-N are twice as high in the effluent of filter number 2 as in the others. The NO_3-N average concentration for filter number 2 was 1.0 mg/l while the other filters' winter averages were 2.5 mg/l and above. Average winter DO concentration for filter 2 is almost as high as the other filters, but this is likely due to agitation and aeration as the water flowed from the sample ports. A very objectionable odor accompanied the effluent of filter number 2.

The reduction of effluent quality from all of the filters during cold weather operations indicates the decrease in biological activity. This is especially evident in the nitrification of ammonia. There was some nitrification under the forced anaerobic conditions on filter number 2. Also, cold weather reduced nitrification in all of the filters.

In their review of intermittent sand filter operation during cold weather, Metcalf and Eddy (1935) state that frost can increase bed porosity. If the frost is allowed to go deep (by letting the sand surface freeze or not having a protective ice cover over the surface) the effluent quality will suffer. During winter weather filters may be furrowed so a protective ice cover can form to prevent filter freezing which may open cracks through which raw water may escape (Fair, Geyer, and Okun, 1968). Filter number 4 utilized stakes to keep the ice sheets from freezing to the sand surface, but the stakes also broke up these ice sheets. No protection was afforded the filter from freezing and a crack apparently developed through the sand in early spring. Filter 4 never plugged, but was taken out of service because an analysis of each sample port revealed that effluent quality from one port was nearly the same quality as the influent. The other two ports maintained a high effluent quality.

TABLE 8. AVERAGE OF ALL SAMPLES COLLECTED DURING WINTER (1974-75) OPERATION

Filter No.	Treatment	BOD_5 mg/1	COD mg/1	SS mg/1	VSS mg/1	Total Phos-phorus mg/1	$O\text{-}PO_4\text{-}P$ mg/1	$NH_3\text{-}N$ mg/1	$NO_2\text{-}N$ mg/1	$NO_3\text{-}N$ mg/1	pH	Temp. °C	DO mg/1
Influent		18	64	28	26	3.5	2.9	5.0	<0.1	0.1	8.6	3.3	9.9
1	0.4 MGAD, furrowed	4	18	4	3	3.1	2.9	1.1	<0.1	4.3	7.5	3.0	8.0
2	0.4 MGAD, head maintained	9	33	10	8	3.1	2.8	4.6	<0.1	1.0	7.9	2.8	7.8
4	0.4 MGAD, staked	4	19	5	4	3.2	3.0	1.8	<0.1	5.1	7.7	2.7	8.6
5	0.4 MGAD, no modification	3	18	3	3	3.2	3.1	2.0	<0.1	3.2	7.7	2.7	8.6
6	0.2 MGAD, no modification	4	17	3	3	3.1	2.9	2.3	<0.1	2.5	7.7	2.2	8.3

1 MGAD = 9354 m^2/hectare-day.

The length of filter runs during the winter experimental period are shown in Table 9. The length of run varied from 58 days for the filter which was raked to 130 days for the furrowed filter. Four of the filters had a hydraulic loading rate of 3742 m^3/ha.d (0.4 MGAD). There was some carry-over of higher loading rate effects, as filter run length decreased on the filters which had formerly been loaded heavily. Filter number 6 had a filter run length of 188 days; however, the hydraulic loading rate was only 1871 m^3/ha.d (0.2 MGAD).

FILTER PERFORMANCE EVALUATION

Further data analysis is given in this section in an effort to bring more insight into the operation of the intermittent sand filter. The validity of some conclusions already presented, possible predictive tools for filter performance and the optimum hydraulic loading rate are discussed.

Run Analysis

The uncontrollable variables inherent in the operation of a prototype intermittent sand filter system negates the possibility of running sophisticated statistical tests. The main problem in establishing statistical control was having enough filter units run at the same hydraulic loading rate so variations could be accounted for. Because of this, qualitative analysis must be accepted where conclusions backed by statistical significance would be preferred.

Although no statistical significance can be developed, the percent removal data calculated for each filter run in Appendix A-1 and for every sample reported in Appendix B help in understanding removal patterns. Two questions to be answered from the Introduction deal with removal from one run to another. Analysis of percent removal in Appendix A-1 shows a general constant improvement in BOD_5 removal except in winter. No pattern can be seen from COD removal since one filter shows constant improvement between runs, another shows fluctuations and another shows an initial increasing trend followed by a constant decrease. After ‘‘washing-out,’’ all filters show a constant improvement for SS removal from one run to another and a trend of improvement for VSS removal also. Total phosphorus removal had an initial increase, followed by a decrease during cold weather and an increase after that. The removal of O-PO_4-P shows fluctuations

TABLE 9. LENGTH OF FILTER RUN FOR WINTER OPERATIONAL PERIOD

Mode of Operation	Filter No.	Hydraulic Loading Rate (MGAD)	Length of Filter Run (Days)
Control	6	0.2	188
Furrowed	1	0.4	130
Flooded	2	0.4	73
Staked	4	0.4	92
Control (raked)	5	0.4	58

1 MGAD = 9354 m^3/hectare-day.

between runs while NH_3-N and NO_3-N removal are very temperature dependent. These results confirm the findings of earlier sections. The trends indicate that a filter's useful life is much longer than one year and that effluent quality will improve to a certain level, then fluctuate about that level. A long range study would be needed to verify these observations, but available literature seems to agree.

By dividing the removal data presented in Appendix B into filter runs, an analysis of removal patterns within each run may be made. When this is done it is realized that algal bloom fluctuations, weather and influent quality variations make performance generalizations within a specific filter run difficult to make. The longer filter runs show a definite increasing trend (negative removal efficiency) to a maximum and then a decreasing of nitrification toward the end of the run. This is verified by Pincince and McKee (1968) who state that the nitrification-aerobic-zone decreases as the filter plugs. Possible trends in BOD_5 and SS removal within a filter run are too general to be accurately defined.

Another question to be answered from the Introduction concerns predicting filter run lengths. Since scraping is a large part of filter operation, it would be valuable to know how often a filter would need to be scraped in relation to influent quality. An extensive regression analysis was undertaken to correlate the number of days of a filter run to a specific parameter or set of parameters. There were 41 complete filter runs (from start-up to plugging) during the year of filter operation. Only the 36 filter runs which occurred during warm weather were employed in this regression analysis. The five filter runs which occurred during cold weather were excluded from the regression analysis because these particular filter runs were significantly longer than those which occurred during the warm weather and it was felt that these extremely long filter runs would bias the results. Also the influent suspended solids to the filters was relatively low during the cold weather and may not be representative of typical lagoon effluent.

All 12 filter influent and effluent water quality parameters in addition to influent algal cell concentrations were employed in the regression analysis. Regression analysis between length of filter run versus average effluent quality, length of filter run versus percent removal; and length of filter run versus pounds of a specific parameter removed (except for pH, temperature, and dissolved oxygen) were conducted. The results of this extensive regression analysis indicated that length of filter run versus the pounds of suspended solids removed for a specific filter run achieved the highest correlation coefficient (0.7867) and was statistically significant at the 99 percent level. The regression analysis of filter run length versus total pounds of COD, VSS, NH_3-N, and NO_3-N removed for a specific filter run was also significant at the 99 percent level, but the correlation coefficients were slightly less than the correlation for suspended solids.

The results of the logarithmic regression analysis of length of filter run versus pounds of suspended solids removed for each specific filter run are shown in logarithmic form in Figure 26 and in normal form in Figure 27. The equation of the line in Figure 27 is $Y = 5240 X^{-1.204}$.

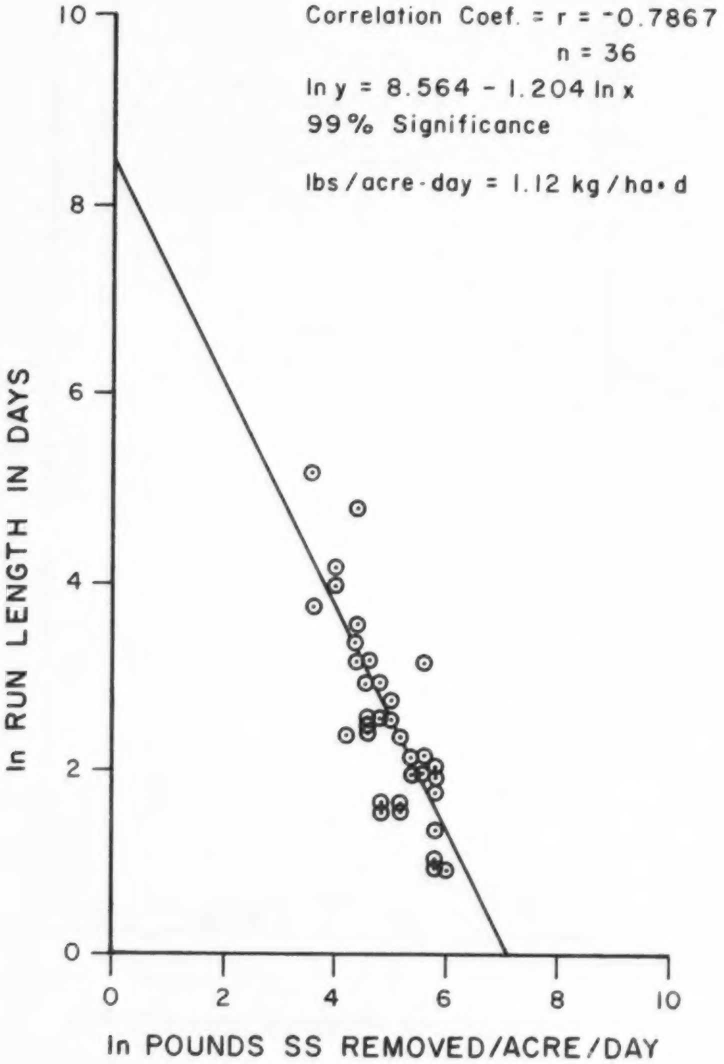


Figure 26. Natural logarithmic plot correlating run lengths to daily pounds suspended solids removed per acre per day.

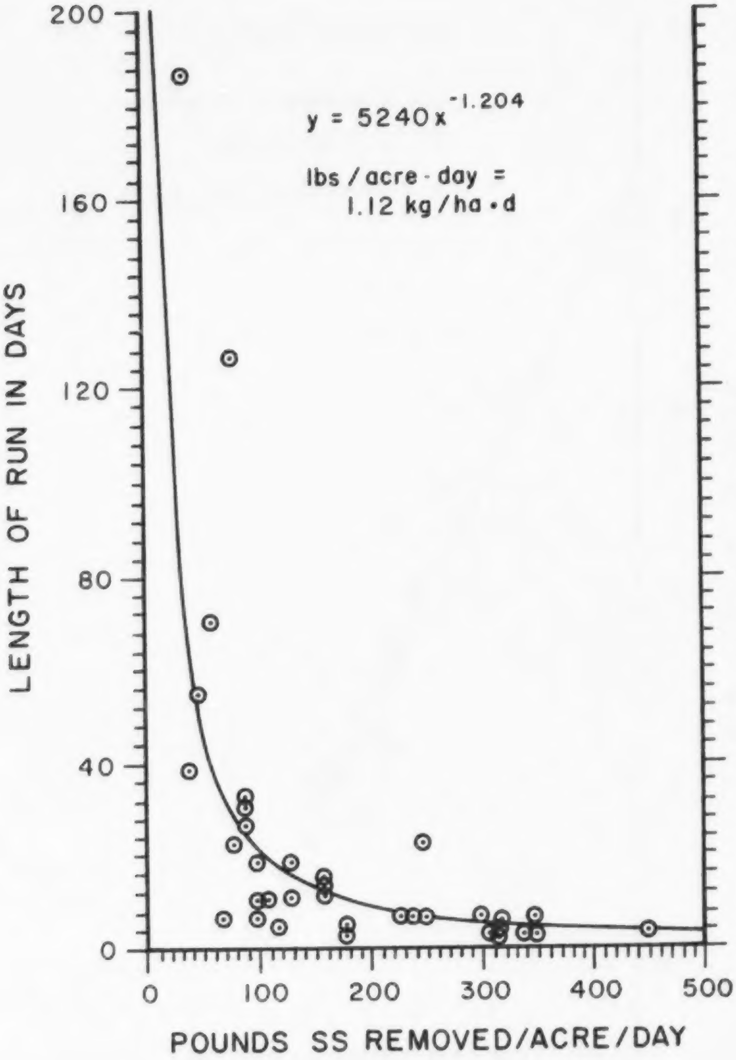


Figure 27. Normal plot correlating run lengths to daily pounds suspended solids removed per acre per day.

To determine the validity of the regression analysis of Figures 26 and 27 in predicting filter run length, suspended solids removal data from two previous studies were analyzed using the equation of Figure 27 (i.e., $Y = 5240\ X^{-1.204}$; where Y = length of filter run in days and X = pounds of suspended solids removed/acre/day). The first data set was collected by Laak (1970) on intermittent sand filters with an effective size filter sand of 0.26 mm and a uniformity coefficient of 1.94. With an influent suspended solids concentration of 70 mg/l and hydraulic loading rates of 2900 and 4958 m^3/ha.d (0.31 and 0.53 MGAD), Laak achieved filter run lengths of 106 and 76 days, respectively. Assuming a 90-95 percent suspended solids removal efficiency and applying the results of Figure 27, indicate a predicted filter run length of only 13 days for the filter loaded at 2900 m^3/ha.d (0.31 MGAD) and 8 days for the filter loaded at 4958 m^3/ha.d (0.53 MGAD). Thus there is an 88 percent difference between the predicted and the actual length of filter run.

The second data set was reported by Marshall and Middlebrooks (1974). Their study employed filter sand with an effective size of 0.17 mm and a uniformity coefficient of 9.74 with hydraulic loading rates of 3742, 4677, 5613, 6548, and 7484 m^3/ha.d (0.4, 0.5, 0.6, 0.7, and 0.8 MGAD) and achieved filter run lengths of 75, 75, 68, 28, and 28 days, respectively. Assuming a 95 percent removal efficiency and using Figure 27, the predicted filter run lengths are 36, 30, 27, 8, and 7 days, respectively. Again, there is a significant difference between the predicted length of filter run and the actual length of filter run reported by Marshall and Middlebrooks (1974) (ranging from 52 percent at 3742 m^3/ha.d to 75 percent at 7484 m^3/ha.d).

The substantial difference between the predicted and actual length of filter run may be due to different effluent characteristics, different filter sands, environmental conditions (i.e., temperature, pH, etc.), mode of operations or the nature of the influent algae. Arnimelech and Nevo (1964) have suggested that the clogging of sands may be a function of the influent carbon to nitrogen ratio. Data were not available on the previous studies (Marshall and Middlebrooks, 1974; Laak, 1970) to evaluate the effects on the carbon to nitrogen ratio.

It is obvious from the above comparison that the lengths of filter runs predicted from Figures 26 and 27 are relatively conservative and provide only a gross approximation of achievable filter run lengths.

Pounds Removed

Data for this section may be found in Appendices C-1 through C-3 where the pounds of BOD_5, COD, SS, VSS, Total P, O-PO_4-P, NH_3-N, NO_2-N and NO_3-N removed (or added) for each sample day, each filter run and each season are listed for all the filters.

The hydraulic loading rates used in this study all resulted in the filters achieving high, and fairly comparable, effluent quality. Slightly better removal efficiencies are achieved by the lower loaded filters, but the difference may be insignificant. An evaluation of hydraulic loading rate performance must therefore include something more than effluent quality or removal efficiency. Table 10 is an attempt to summarize and compare the overall ‘‘value’’ of each filter during the experimental period.

TABLE 10. FILTER PERFORMANCE SUMMARY

Hydraulic Loading (MGAD)[a]	0.2	0.4	0.6	0.8	1.0	1.0
Filter Number	6	1	2	3	4	5
Period of Operation	7/2-6/27	7/2-6/27	7/2-6/8	7/2-10/21	7/2-5/14	7/2-6/16
Days of Operation	361	361	342	112	317	350
Days Filled	321	293	219	75	208	167
Days Not Filled	4	10	17	3	4	3
Days Down	36	58	106	34	105	180
Times Cleaned	3	5	8	4	8	12
Ave. Days Down/Plug	12.0	11.6	13.3	8.5	13.1	15.0
% Down Time	10.0	16.1	31.0	30.4	33.1	51.4
Water Filtered (10^6 gal/acre)[b]	64.2	117.2	131.4	60.0	208.0	167.0
Total Pounds Removed:[c]						
BOD_5	170	355	289	57	210	160
COD	473	937	825	297	777	580
SS	260	514	464	200	455	364
VSS	200	387	339	127	358	287
Total-P	4.3	9.7	9.0	4.7	5.6	2.6
$O-PO_4-P$	-1.0	2.0	2.7	1.0	-1.4	-2.2
NH_3-N	32.9	56.2	34.8	21.9	56.0	43.0
NO_2-N	<0.1	-1.0	-1.7	-1.4	-2.6	-2.9
NO_3-N	-53.1	-84.0	-69.4	-34.7	-70.7	-68.5

[a] 1 MGAD = 9354 m^3/hectare·day.

[b] 10^6 gal/acre = 9354 m^3/hectare.

[c] 1 Pound = 0.454 kg.

[d] Summer, fall, and winter values used only.

It should be noted that filter number 3 (7484 m^3/ha.d or 0.8 MGAD) was taken out of service after less than four months of operation because of extensive leaks in the vinyl liner, and filter number 4 (9354 m^3/ha.d or 1.0 MGAD scraped). The four filters which ran during the entire year were 6, 1, 2, and 5. They were loaded with 1871, 3742, 5613 and 9354 m^3/ha.d (0.2, 0.4, 0.6, and 1.0 MGAD) respectively during warm weather and 1871, 3742, 3742, and 3742 m^3/ha.d (0.2, 0.4, 0.4 and 0.4 MGAD) during cold weather. A graphical analysis of these filters' performance is given by Figures 28 and 29.

Nine of the ten plots on Figures 28 and 29 show an apparent linear relationship from one loading rate to another with a breakpoint near 3742 m^3/ha.d (0.4 MGAD). Because of this, loading rates of 3742 to 5613 m^3/ha.d (0.4 to 0.6 MGAD) seem to be optimum for the single stage intermittent sand filter. The selection of this ‘‘optimum’’ hydraulic loading rate is further verified by Fair, Geyer, and Okun (1968) who state that a hydraulic loading rate of 4677 m^3/ha.d (0.5 MGAD) may be successfully used for filtering biological effluents.

The validity of the conclusion reached from Figures 28 and 29 rests on the prejudices introduced by the amount of time each filter was not dosed. Fuller (1908) reported that 13 percent down time could be expected for scraping and maintenance of slow sand filters. Down times for this project ranged form 10 percent to 51 percent. However, this may be viewed with more perspective by realizing that the filters with higher hydraulic loading rates plugged more often. The average number of days down for each filter ranged from 11.6 to 15.0 days. Part of this variation was due to not being able to scrape filter number 5 during the winter because of freezing conditions.

Thomas, Schwartz, and Bendixen (1966) found that phosphate build-up in soil increased to a constant level. This was likely due to adsorption on the soil. Once the adsorption sites in the soil become saturated no further phosphate removal is expected. However, in the present study, each sand filter bed had approximately the same volume of sand and yet phosphorus removal varied with hydraulic loading rate (Table 10). This variability in phosphorus removal (Figure 29) could be due to increased biological activity in those filters where high total phosphorus removal occurred.

Orthophosphate removal seems to follow the same pattern as that established for total phosphorus removal. Table 10 and Figure 29 show that hydrolysis converts organic and polyphosphates to orthophosphate within the filter. There is apparently a greater uptake of the orthophosphates in the 3742 and 5613 m^3/ha.d (0.4 and 0.6 MGAD) loaded filters since these show a net removal of phosphorus whereas the 1871 and 9354 m^3/ha.d (0.2 and 1.0 MGAD) loaded filters show a net gain. Here again, greater biological activity may be the cause of these differences.

No total nitrogen mass balance can be performed from the data taken on this project because organic nitrogen parameters were not measured. However, the pounds of nitrate-nitrogen in the effluent of each filter compared to the pounds of ammonia-nitrogen removed and the amount of ammonia-nitrogen remaining in the filter effluent (see Figure 18) indicate that organic nitrogen is converted to inorganic nitrogen. According to Sawyer and McCarty (1967) organic nitrogen is converted to ammonia by saprophytic bacterial action. This process can take place under aerobic or anaerobic conditions. Ammonia is then converted to

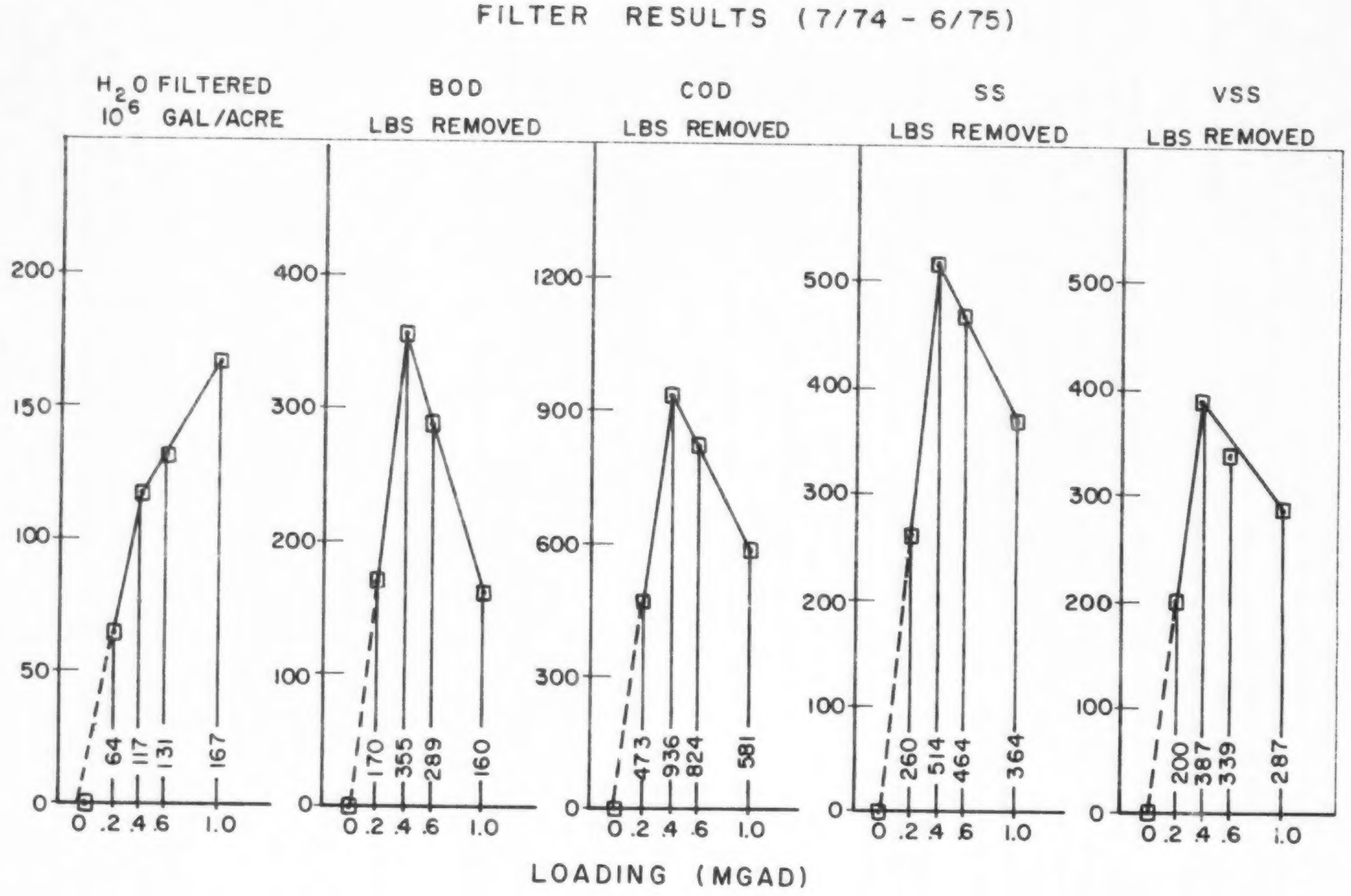


Figure 28. Filter loading comparison graphs for water filtered and total pounds of BOD_5, COD, SS, and VSS removed. 1 MGAD = 9354 m^3/ha.d, 10^6 gal = 3785 m^3, and 1 pound = 0.454 kg.

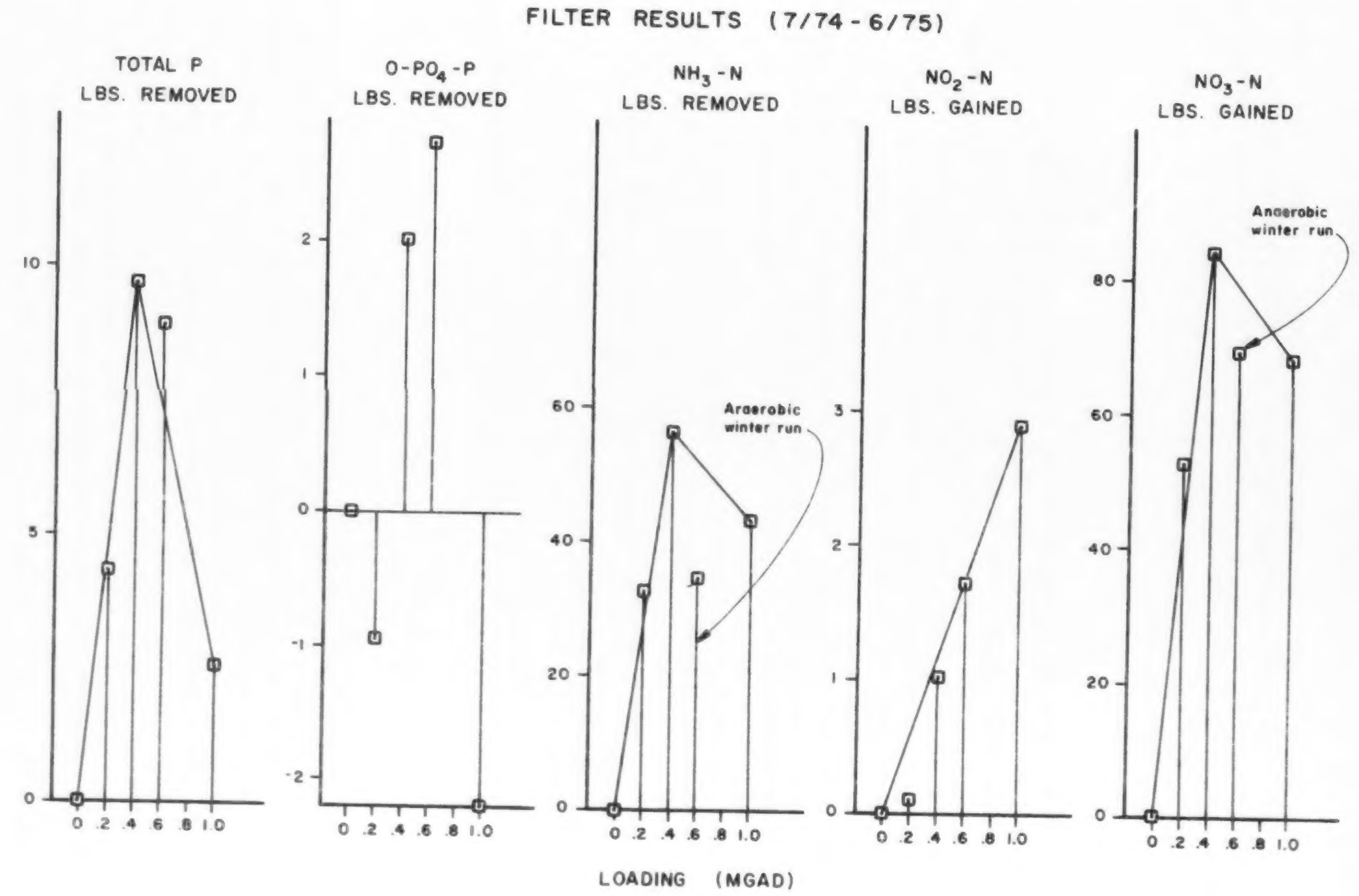


Figure 29. Filter loading comparison graphs for total pounds of Total P, O-PO$_4$-P and NH$_3$-N removed and NO$_2$-N and NO$_3$-N gained. (1 MGAD = 9354 m^3/ha.d, 10^6 gal = 3785 m^3 and 1 pound = 0.454 kg.)

nitrite-nitrogen and nitrate-nitrogen if it is not used directly by any organisms present. It is doubtful that nitrogen fixing within the intermittent sand filter is an important contributor to inorganic nitrogen increases.

A mass balance for nitrogen was performed by Furman, Calaway, and Grantham (1955) who found that the total nitrogen applied to their intermittent sand filters was greater than the total nitrogen recovered. They felt that two mechanisms could have been responsible for this: 1) the nitrogen builds up within the filter bed or 2) there is a loss of nitrogen to the atmosphere during sampling or between loadings.

Filter Run Lengths

It has been found that plugging of an intermittent sand filter increases exponentially with hydraulic loading rate increases (Folkman and Wachs, 1970). Results obtained from this study agree with that conclusion. Figure 30 is an iso-concentration plot of the average suspended solids concentrations added to any given filter over that filter's run. When more than one influent run average fell within the concentration range specified, the run length plotted is an average of all those within the range. The plot verifies findings in the literature. Shorter run lengths result from higher hydraulic loading rates--or plugging increases exponentially with loading rate increases. The plot also verifies the intuitive feeling that for a given hydraulic loading rate, suspended solids concentration increases will cause shorter run lengths.

A plot of average filter run lengths during warm weather are shown in Figure 31 and reported in Table 6. Figure 31 is presented to further aid in the determination of an optimum hydraulic loading rate. The previous section concluded that loading rates of 3742 to 5613 m^3/ha.d (0.4 to 0.6 MGAD) were optimum. Figures 30 and 31 illustrate the trade-offs of low capital costs to high operation costs for higher loading rates or vice versa for lower loading rates. The break-point on each curve seems to be from 2806 to 4677 m^3/ha.d (0.3 to 0.5 MGAD). Local construction costs, amortization period and operational costs will actually dictate the design loading rate with its accompanying filter run lengths.

COST ESTIMATE

Cost estimates for the polishing of lagoon effluents using the intermittent sand filter process have been prepared for a general situation. A detailed break-down of these estimates is presented in Appendices D-1 and D-2. Filter construction costs are relatively easy to calculate and the values presented are an accurate reflection for the intermountain region of the United States. Operation costs, on the other hand, are dependent on several variables. Long filter runs may be expected during low influent concentration periods. Lower costs from not having to scrape filter surfaces will result, but these periods are not predictable. Costs will also depend on the mode of surface cleaning employed. Operating expenses listed in Appendix D are based upon the experience of this study. It is felt that conditions encountered during this study were average with respect to weather, algal blooms, and influent concentrations.

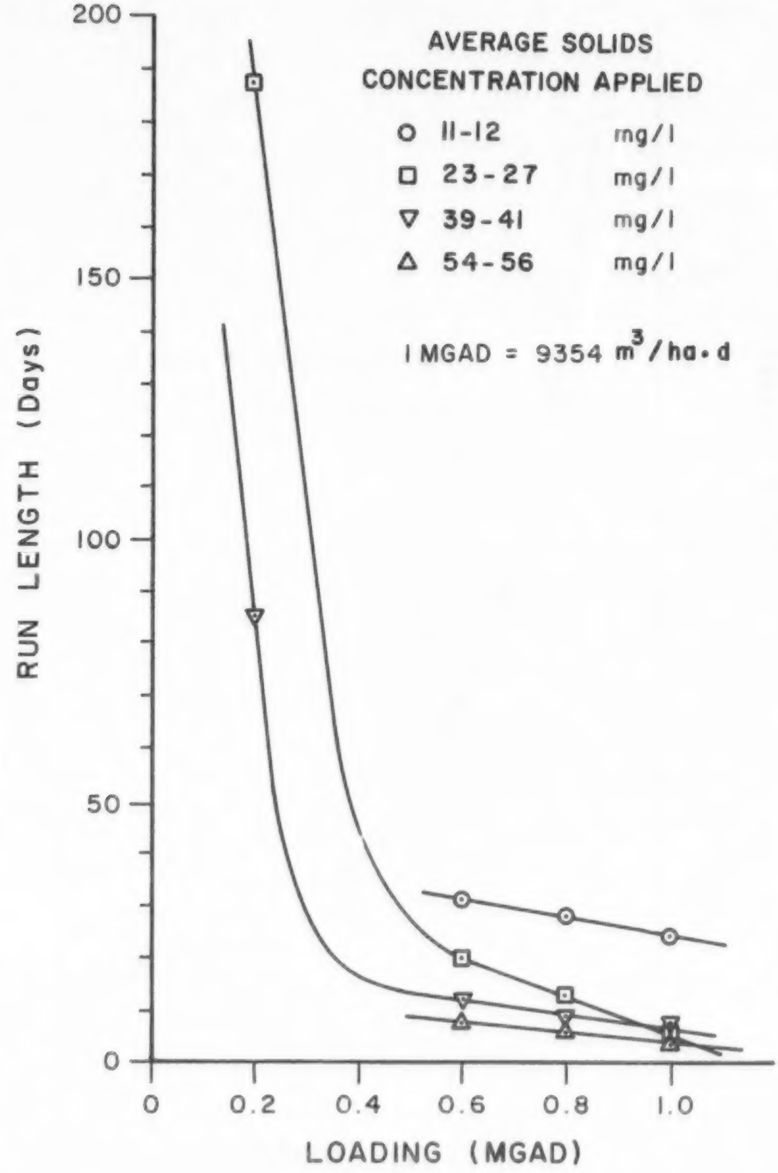


Figure 30. Iso-concentration plot of average suspended solids loaded during a complete run.

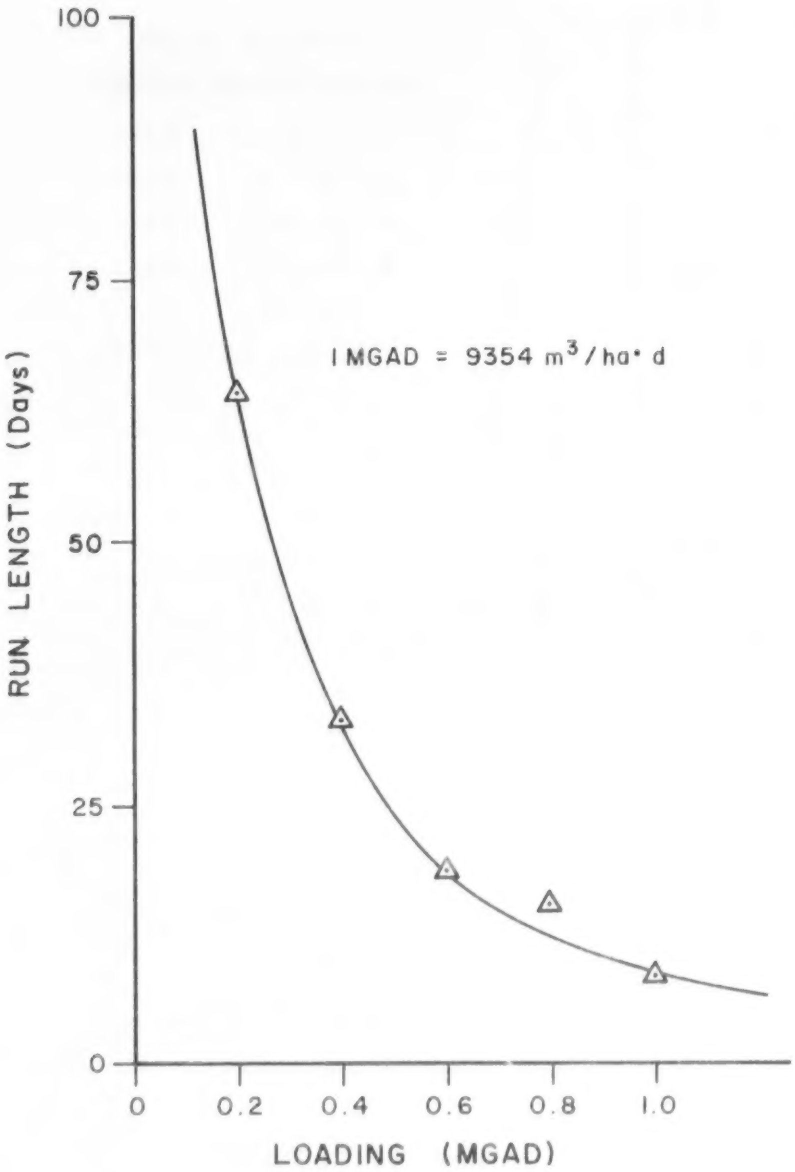


Figure 31. Average length of filter run during warm weather (spring, summer, fall).

Construction cost estimates were prepared with the aid of local contractors and engineering consulting firms. They represent the outlay necessary to construct a typical intermittent sand filter process in the intermountain area during November 1974. The filter sand used (0.17 mm effective size, 9.74 uniformity coefficient) was locally available with no special processing.

Table 11 summarizes the two cost estimates given in Appendix D. The construction costs calculated in Estimate I reflect a paired bed operation, designed at 5613 m^3/ha.d (0.6 MGAD) for a design waste flow of 1893 m^3/day (0.5 MGD) and with a 3 hour influent filter loading period. The estimate is calculated for both federally subsidized (at 75 percent of the construction cost) and independently financed construction. Details of Estimate I are presented in Appendix D-1.

Estimate II represents construction costs for a filter system utilizing the final cell of a multi-cell lagoon system. No land purchase is needed in this case, and modification of the final cell for the paired filter bed would require only one-fourth of the dike construction costs required in Estimate I. All other values and assumptions in Estimate I are applied here. Estimate II is developed in Appendix D-2.

From the limited operating experience gained and conditions encountered during this study, capital costs (1974) ranging from $8.70 to $18.50 per 1000 m^3 ($33 to $70 per million gallons) filtered are assumed to be representative of the intermittent sand filter polishing process.

TABLE 11. ESTIMATED COST PER MILLION GALLONS OF FILTRATE PRODUCED BY VARIOUS DESIGNS OF AN EFFLUENT POLISHING INTERMITTENT SAND FILTER PROCESS (NOVEMBER 1974) (HARRIS ET AL., 1975)

Application Conditions	Design Capacity	Design Hydraulic Loading Rate	Effective Sand Size	Cost With Federal Assistance $/$10^6$ Gallons	Cost Without Federal Assistance $/$10^6$ Gallons
Paired Bed Operation (Estimate I)	0.5 MGD	0.6 MGAD	0.17 mm	$33	$62
Modification of Existing Lagoon (Estimate II) (Paired Bed)	0.5 MGD	0.6 MGAD	0.17 mm	$31	$56

1 MGD = 3785 m^3/d.

1 MGAD = 9354 m^3/hectare·day.

$1.00/$10^6$ gal = $0.264/1000 m^3.

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Appendix A

1. Filter Effluent Quality with Run Summarizations Including Influent and Effluent Averages and Percent Removals
2. Seasonal Influent and Effluent Averages and Percent Removals for Each Filter

1 MGAD = 9354 m^3/hectare-day

TABLE A-1-1. INFLUENT QUALITY FOR EACH SAMPLE DAY

INFLUENT DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NC2-N (MG/L)	NO3-N (MG/L)
JUL 2	TERTIARY	21.0	2.2	8.80	3.5	37.0	10.9	2.6	3.330	3.192	3.370	0.174	0.784
12	SECONDARY	21.0	2.2	8.80	8.1	64.5	24.9	17.1	2.112	1.760	1.877	0.022	0.166
15	SECONDARY	-5.0	-5.0	-5.00	-5.0	-5.0	8.2	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
17	SECONDARY	24.5	1.6	-5.00	8.1	75.0	10.0	4.2	-5.000	1.928	3.378	0.019	0.121
18	TERTIARY	-5.0	-5.0	-5.00	-5.0	-5.0	7.4	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
19	TERTIARY	-5.0	-5.0	-5.00	-5.0	-5.0	5.6	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
22	TERTIARY	-5.0	-5.0	-5.00	-5.0	-5.0	5.9	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
24	SECONDARY	24.5	3.4	8.85	4.0	89.8	10.9	6.4	2.204	2.059	3.359	0.027	0.054
26	SECONDARY	-5.0	-5.0	-5.00	-5.0	-5.0	23.4	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
31	SECONDARY	-5.0	3.4	8.46	14.3	54.8	16.8	11.5	2.313	2.076	2.499	0.027	0.054
AUG 6	SECONDARY	-5.0	-5.0	-5.00	-5.0	-5.0	72.1	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
7	SECONDARY	22.9	10.5	8.90	6.0	64.4	39.3	31.5	1.699	0.959	1.233	0.029	0.084
14	SECONDARY	19.9	10.9	9.20	12.9	84.8	55.7	44.3	1.807	0.985	0.168	0.007	0.043
16	SECONDARY	-5.0	-5.0	-5.00	-5.0	-5.0	55.2	39.2	-5.000	-5.000	-5.000	-5.000	-5.000
19	SECONDARY	-5.0	-5.0	-5.00	-5.0	-5.0	51.9	40.8	-5.000	-5.000	-5.000	-5.000	-5.000
21	SECONDARY	19.0	5.9	9.10	6.3	78.3	56.9	36.6	1.893	1.054	0.091	0.002	0.116
SEP 4	SECONDARY	19.2	12.5	8.80	8.8	91.3	50.4	39.1	1.721	0.954	0.120	0.001	0.020
6.	SECONDARY	-5.0	-5.0	-5.00	-5.0	-5.0	43.9	27.2	-5.000	-5.000	-5.000	-5.000	-5.000
9	SECONDARY	-5.0	-5.0	-5.00	10.4	-5.0	34.0	26.2	-5.000	-5.000	-5.000	-5.000	-5.000
11	SECONDARY	19.0	10.6	8.70	6.4	65.5	30.8	20.8	1.517	1.071	0.395	0.006	0.046
18	SECONDARY	17.1	14.7	8.70	6.4	37.0	14.0	8.6	1.424	1.139	0.820	0.017	0.072
20	SECONDARY	-5.0	-5.0	-5.00	8.0	-5.0	13.8	7.8	-5.000	-5.000	-5.000	-5.000	-5.000
26	SECONDARY	16.8	7.1	8.37	3.9	27.9	22.7	11.5	2.154	1.909	2.259	0.014	0.037
OCT 3	SECONDARY	15.1	7.2	8.18	6.4	33.8	16.5	6.0	2.488	2.222	4.602	0.015	0.031
10	SECONDARY	13.9	8.3	8.34	7.7	36.4	23.1	11.4	5.387	1.933	3.832	0.013	0.067
17	SECONDARY	11.9	10.6	8.40	10.4	35.4	28.9	8.9	2.397	2.090	1.906	0.039	0.140
24	SECONDARY	11.9	8.1	8.40	19.3	66.2	43.5	33.5	2.714	1.880	2.516	0.055	0.052
31	SECONDARY	9.5	8.0	8.19	22.0	42.7	33.3	25.3	2.377	1.915	2.378	0.042	0.166
NOV 7	SECONDARY	7.1	8.2	8.17	12.0	33.4	26.1	18.2	3.015	2.223	6.287	0.042	0.112
14	SECONDARY	5.8	12.9	8.72	19.9	53.0	40.8	29.5	2.637	2.173	2.693	0.037	0.196
21	SECONDARY	5.1	9.8	8.72	8.7	34.1	22.7	11.5	2.193	2.151	5.460	0.034	0.113
26	SECONDARY	4.1	11.8	8.29	13.3	36.9	32.8	18.2	2.767	2.372	4.407	0.020	0.102

(Continued)

TABLE A-1-1. (CONTINUED)

DEC 5	SECONDARY	3.7	16.0	8.95	19.2	45.8	23.4	18.1	2.672	2.264	3.841	0.035	0.203
12	SECONDARY	2.7	12.0	8.81	22.7	57.7	30.7	26.9	2.870	2.132	3.769	0.029	0.171
19	SECONDARY	3.4	15.6	8.87	10.0	34.9	14.9	11.9	2.409	2.175	4.896	0.034	0.165
26	SECONDARY	2.1	14.0	8.82	16.7	68.8	19.1	16.6	2.950	2.564	6.581	0.029	0.204
JAN 2	SECONDARY	2.8	4.6	8.49	8.5	34.0	8.6	6.8	2.896	2.774	4.916	0.027	0.134
9	SECONDARY	3.0	3.8	8.46	5.3	31.2	5.5	4.0	3.137	2.863	3.118	0.032	0.105
16	SECONDARY	3.0	3.2	8.00	12.1	43.7	11.3	6.0	3.375	3.127	6.650	0.021	0.052
23	SECONDARY	2.0	0.2	8.20	12.5	46.2	13.4	11.6	3.802	3.529	7.621	0.002	0.020
30	SECONDARY	2.0	4.0	8.15	19.7	61.8	24.9	22.3	3.852	3.393	5.656	0.003	0.019
FEB 6	SECONDARY	2.0	5.4	8.00	28.1	71.9	28.7	27.2	4.091	3.422	6.059	0.006	0.028
13	SECONDARY	2.5	12.9	8.30	22.4	80.7	39.4	39.4	3.896	3.109	5.418	0.023	0.042
20	SECONDARY	3.6	21.9	8.95	25.7	70.0	42.3	40.2	3.932	2.477	4.687	0.006	0.053
27	SECONDARY	3.5	18.9	8.88	23.4	78.9	37.9	36.7	3.466	2.702	3.998	0.011	0.099
MAR 6	SECONDARY	4.5	18.1	9.01	18.1	90.8	43.8	40.4	3.606	2.758	4.200	0.014	0.085
13	SECONDARY	4.9	9.5	8.70	17.0	74.3	38.6	36.0	2.951	2.097	2.858	0.014	0.077
20	SECONDARY	6.7	12.6	9.50	23.1	83.0	54.7	45.9	3.200	2.446	5.732	0.029	0.180
27	SECONDARY	2.5	10.0	8.62	20.2	82.9	51.1	42.1	3.292	2.487	5.793	0.042	0.122
APR 3	SECONDARY	4.7	12.3	8.80	21.6	83.4	48.0	38.4	3.024	2.374	1.710	0.032	0.214
10	SECONDARY	6.1	3.6	8.27	15.2	61.6	26.5	18.6	3.215	2.508	2.466	0.040	0.220
17	SECONDARY	6.7	4.3	7.94	10.9	54.9	21.5	11.1	3.234	2.542	4.011	0.043	0.199
24	SECONDARY	10.1	6.7	8.10	25.1	50.3	25.2	12.2	3.234	2.813	4.582	0.051	0.151
MAY 1	SECONDARY	10.5	12.0	8.56	10.2	55.2	32.4	22.3	3.032	2.689	2.811	0.069	0.283
8	SECONDARY	10.0	-5.0	8.70	13.4	60.6	43.6	27.6	2.975	2.336	1.999	0.077	0.431
15	SECONDARY	13.5	12.8	8.90	10.3	45.9	19.9	14.2	2.377	1.902	1.804	0.083	0.402
22	SECONDARY	12.1	6.2	8.90	5.4	36.0	7.9	4.6	1.977	1.412	1.060	0.083	0.571
29	SECONDARY	15.1	4.5	8.50	48.4	140.8	87.5	69.0	5.097	3.407	1.864	0.072	0.260
JUN 5	SECONDARY	17.7	0.7	8.40	288.0	440.9	130.2	109.1	4.866	2.084	2.302	0.059	0.200
12	SECONDARY	18.0	2.8	8.28	8.5	38.6	19.9	15.6	3.080	2.428	3.296	0.013	0.037
19	SECONDARY	17.2	1.1	8.00	7.1	44.7	12.2	5.6	2.871	2.428	2.361	0.019	0.047
26	SECONDARY	16.5	1.0	7.68	10.0	66.2	26.9	16.9	3.404	3.193	4.530	0.033	0.095

* NOTE: -5.0 INDICATES MISSING DATA

TABLE A-1-2. EFFLUENT QUALITY AND RUN SUMMARY FOR FILTER 1

FILTER 1 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
JUL 2	0.5	-5.0	-5.0	-5.00	2.4	25.0	2.7	0.0	1.631	1.442	2.538	1.040	0.791
12	0.4	24.0	7.0	8.10	2.6	20.4	30.9	2.5	1.508	1.314	0.456	0.058	7.130
15	0.4	-5.0	-5.0	-5.00	-5.0	-5.0	1.7	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
17	0.4	25.5	5.9	-5.00	1.0	69.0	7.6	0.0	-5.000	1.250	0.231	0.018	8.933
18	0.4	-5.0	-5.0	-5.00	-5.0	-5.0	9.1	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
19	0.4	-5.0	-5.0	-5.00	-5.0	-5.0	11.4	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
22	0.4	-5.0	-5.0	-5.00	-5.0	-5.0	1.9	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
24	0.4	25.3	6.3	8.13	1.9	21.9	2.5	1.1	1.676	1.530	0.081	0.007	2.027
26	0.4	-5.0	-5.0	-5.00	-5.0	-5.0	1.8	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
31	0.4	24.2	5.6	7.74	1.3	16.1	1.7	0.9	1.870	1.861	0.136	0.031	5.136
AUG 6	0.4	-5.0	-5.0	-5.00	-5.0	-5.0	2.0	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
7	0.4	23.0	5.9	8.10	1.7	11.4	2.9	2.3	1.324	1.335	0.082	0.011	1.453
RUN NUMBER 1 -		7/2-8/7											
MEAN: INFLUENT		22.8	3.9	8.76	7.3	64.3	19.6	12.2	2.332	1.996	2.619	0.050	0.211
EFFLUENT		24.4	6.1	8.02	1.8	27.3	6.4	1.1	1.602	1.455	0.587	0.194	4.245
PERCENT REMOVAL:		-7.	-58.	8.	75.	58.	68.	91.	31.	27.	78.	-291.	-1917.
14	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
16	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
19	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
21	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
SEP 4	0.4	20.2	7.5	7.70	2.4	27.5	9.4	3.0	1.279	1.227	0.130	0.025	3.609
6	0.4	-5.0	-5.0	-5.00	-5.0	-5.0	4.9	1.4	-5.000	-5.000	-5.000	-5.000	-5.000
9	0.4	-5.0	-5.0	-5.00	2.2	-5.0	2.3	0.0	-5.000	-5.000	-5.000	-5.000	-5.000
11	0.4	19.1	7.2	7.70	2.0	22.4	3.3	1.6	0.864	0.805	0.125	0.244	1.751
18	0.4	19.4	7.2	7.40	0.8	15.6	1.3	0.6	0.781	0.805	0.140	0.155	2.709
20	0.4	-5.0	-5.0	-5.00	0.4	-5.0	1.2	0.2	-5.000	-5.000	-5.000	-5.000	-5.000
26	0.4	18.1	7.4	7.80	1.2	16.3	0.6	0.2	1.193	1.209	0.222	0.045	1.613
RUN NUMBER 2 -		9/4-9/28											
MEAN: INFLUENT		18.0	11.2	8.64	7.3	55.4	29.9	20.2	1.704	1.268	0.899	0.010	0.044
EFFLUENT		19.2	7.3	7.65	1.5	20.5	3.3	1.0	1.029	1.012	0.154	0.117	2.421
PERCENT REMOVAL:		-7.	35.	11.	79.	63.	89.	95.	40.	20.	83.	-1134.	-5433.
OCT 3	0.4	14.8	7.4	7.67	1.8	16.9	1.7	0.1	1.866	1.777	0.951	0.245	3.199
10	0.4	14.4	7.7	7.74	1.3	13.2	1.2	0.6	5.124	2.396	0.176	0.012	4.910
17	0.4	13.0	7.4	7.50	1.2	10.6	2.7	0.7	2.373	2.285	0.193	0.008	6.201
24	0.4	12.2	7.5	7.70	1.7	11.8	1.3	0.2	2.024	1.872	0.089	0.070	4.510
31	0.4	10.3	7.7	7.78	2.1	13.7	0.7	0.6	1.383	1.660	0.396	0.039	0.897

(Continued)

TABLE A-1-2. (CONTINUED)

RUN NUMBER 3 - 10/2-11/3													
MEAN: INFLUENT		12.5	8.4	8.30	13.2	42.9	29.1	17.0	3.073	2.008	3.047	0.033	0.091
EFFLUENT		12.9	7.5	7.68	1.6	13.2	1.5	0.4	2.554	1.998	0.361	0.075	3.943
PERCENT REMOVAL:		-4.	11.	8.	88.	69.	95.	97.	17.	0.	88.	-128.	-4224.
NOV 7	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
14	0.4	6.5	8.4	7.50	1.3	25.1	1.5	1.0	1.970	2.043	0.774	0.196	7.746
21	0.4	5.5	7.9	7.89	1.7	14.5	1.3	0.6	2.222	2.179	1.029	0.164	6.261
26	0.4	4.1	10.0	7.62	1.4	10.7	1.8	0.8	2.767	2.561	0.842	0.021	4.940
DEC 5	0.4	4.0	9.9	7.58	1.4	11.8	1.6	1.0	2.641	2.385	0.728	0.140	10.398
12	0.4	3.3	6.8	7.55	2.0	12.0	2.2	1.6	2.519	2.236	0.779	0.023	6.707
19	0.4	2.2	8.9	7.60	1.8	13.4	2.0	1.5	2.307	2.219	0.782	0.028	5.245
26	0.4	3.0	14.4	7.55	1.4	13.5	1.2	0.9	2.718	2.548	0.744	0.043	5.993
JAN 2	0.4	1.5	4.0	7.44	1.4	12.9	0.9	0.8	2.697	2.605	0.983	0.034	6.406
9	0.4	1.0	7.2	7.50	1.7	12.8	1.2	1.1	2.950	2.835	1.708	0.019	4.946
16	0.4	1.8	7.3	7.37	2.4	12.9	1.5	0.3	3.025	2.793	2.923	0.031	8.134
23	0.4	1.5	7.1	7.42	3.3	15.0	2.1	2.0	3.498	3.468	2.326	0.026	5.945
30	0.4	1.5	7.6	7.20	7.5	12.8	2.8	2.5	3.570	3.393	1.283	0.024	6.586
FEB 6	0.4	2.0	8.7	7.45	5.2	22.6	4.1	3.8	3.574	3.422	0.746	0.017	3.655
13	0.4	2.7	8.7	7.45	4.4	19.5	5.4	5.4	3.435	3.093	0.628	0.090	5.199
20	0.4	2.7	9.3	7.62	3.5	14.0	3.8	3.3	2.955	2.879	0.376	0.010	1.088
27	0.4	3.2	6.5	7.57	4.7	22.5	6.6	6.0	3.023	3.022	0.675	0.018	5.850
MAR 6	0.4	5.1	7.7	7.88	5.7	24.9	6.5	6.1	5.727	2.909	1.098	0.019	0.817
13	0.4	5.9	7.8	7.60	4.8	26.6	5.0	4.9	2.861	2.547	0.901	0.021	0.791
20	0.4	6.5	7.4	7.95	6.8	23.3	4.9	4.7	2.554	2.308	0.548	0.019	0.940
RUN NUMBER 4 - 11/13-3/22													
MEAN: INFLUENT		3.5	10.9	8.62	17.2	57.8	28.1	23.6	3.195	2.660	4.872	0.021	0.108
EFFLUENT		3.4	8.2	7.57	3.3	16.9	3.0	2.5	3.001	2.708	1.046	0.050	5.139
PERCENT REMOVAL:		5.	25.	12.	81.	71.	89.	89.	6.	-2.	79.	-132.	-4668.
27	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
APR 3	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
10	0.4	6.5	7.3	7.37	4.8	21.7	2.5	2.5	2.508	2.133	0.285	0.015	0.948
17	0.4	7.9	7.0	7.14	3.2	20.5	1.0	0.8	2.656	2.310	1.122	0.043	1.100
24	0.4	11.2	6.6	7.60	3.8	20.3	0.7	0.5	2.671	3.034	0.909	0.055	1.522
MAY 1	0.4	10.5	6.2	7.32	2.8	19.5	0.9	0.8	2.770	2.672	0.500	0.066	1.581
8	0.4	9.0	-5.0	7.60	1.9	11.6	0.7	0.6	2.320	2.288	0.258	0.060	1.347

(Continued)

TABLE A-1-2. (CONTINUED)

RUN NUMBER 5 - 4/5-5/10													
MEAN: INFLUENT		8.7	6.7	8.31	15.0	56.5	29.8	18.4	3.138	2.578	3.174	0.056	0.257
EFFLUENT		9.0	6.8	7.41	3.3	18.7	1.1	1.0	2.585	2.487	0.615	0.048	1.300
PERCENT REMOVAL:		-4.	-2.	11.	78.	67.	96.	94.	18.	3.	81.	15.	-406.
15	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
22	0.4	13.2	6.6	7.30	1.0	11.6	1.3	0.6	1.270	1.318	0.145	0.015	5.186
29	0.4	15.7	6.1	7.30	1.0	15.5	1.1	0.6	3.165	3.006	0.105	0.043	6.750
JUN 5	0.4	19.4	4.6	7.25	1.2	15.4	1.0	0.5	2.348	2.230	0.226	0.149	7.030
12	0.4	20.0	5.0	7.40	1.7	12.5	1.4	0.7	2.360	2.272	0.294	0.104	5.485
19	0.4	17.0	5.6	7.50	2.3	10.7	1.1	0.5	3.157	2.871	0.333	0.104	5.911
26	0.4	17.0	6.9	7.10	2.2	12.1	2.5	0.6	3.263	2.895	0.426	0.023	10.088
RUN NUMBER 6 - 5/17-6/27													
MEAN: INFLUENT		16.1	2.7	8.29	61.2	127.9	47.4	36.8	3.549	2.492	2.569	0.047	0.202
EFFLUENT		16.9	5.8	7.31	1.6	13.0	1.4	0.6	2.594	2.432	0.255	0.073	6.742
PERCENT REMOVAL:		-5.	-113.	12.	97.	90.	97.	98.	27.	2.	90.	-57.	-3243.

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE A-1-3. EFFLUENT QUALITY AND RUN SUMMARY FOR FILTER 2

FILTER 2 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
JUL 2	0.8	-5.0	-5.0	-5.00	2.2	27.0	3.2	0.8	3.057	2.981	1.637	0.982	1.823
12	0.6	21.0	7.0	8.10	3.7	26.1	29.6	3.6	1.986	1.672	0.474	0.191	8.702
15	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	4.2	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
17	0.6	25.5	5.7	-5.00	1.4	16.0	22.4	0.7	-5.000	1.536	0.385	0.018	9.359
18	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	8.9	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
19	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	19.3	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
22	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	3.3	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
24	0.6	25.1	5.7	8.12	2.0	53.0	3.1	0.5	1.765	1.094	0.058	0.012	1.704
26	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	2.6	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
31	0.6	24.6	4.8	7.68	1.5	19.0	2.2	0.5	2.090	1.961	0.316	0.040	4.329
RUN NUMBER 1 - 7/2-8/5													
MEAN: INFLUENT		22.8	2.6	8.73	7.6	64.2	12.4	8.4	2.490	2.203	2.897	0.054	0.236
EFFLUENT		24.0	5.8	7.97	2.2	28.2	9.9	1.2	2.225	1.849	0.574	0.249	5.183
PERCENT REMOVAL:		-6.	-127.	9.	72.	56.	20.	85.	11.	16.	80.	-362.	-2098.
AUG 6	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	3.9	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
7	0.6	22.3	6.1	8.20	2.7	23.6	7.2	4.8	1.255	1.226	0.231	0.015	0.832
14	0.6	20.1	7.9	8.18	3.2	30.4	9.0	5.4	1.333	1.185	0.113	0.015	1.704
16	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	7.3	3.9	-5.000	-5.000	-5.000	-5.000	-5.000
19	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	3.4	2.3	-5.000	-5.000	-5.000	-5.000	-5.000
21	0.6	19.0	6.3	8.21	1.0	14.6	4.0	2.6	0.946	0.878	0.135	0.008	0.656
RUN NUMBER 2 - 8/14-8/22													
MEAN: INFLUENT		20.6	9.1	9.07	8.4	75.8	55.2	38.5	1.800	0.999	0.497	0.013	0.081
EFFLUENT		20.5	6.8	8.20	2.3	22.9	5.8	3.8	1.178	1.096	0.160	0.013	1.064
PERCENT REMOVAL:		1.	26.	10.	73.	70.	89.	90.	35.	-10.	68.	0.	-1214.
SEP 4	0.6	20.1	7.2	7.80	1.5	30.2	15.4	3.2	0.921	0.901	0.111	0.016	2.868
6	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	3.8	0.8	-5.000	-5.000	-5.000	-5.000	-5.000
9	0.6	-5.0	-5.0	-5.00	2.1	-5.0	3.3	1.0	-5.000	-5.000	-5.000	-5.000	-5.000
11	0.6	20.2	6.3	7.60	0.8	16.8	2.3	1.4	0.841	0.906	0.080	0.075	3.440
RUN NUMBER 3 - 9/4-9/15													
MEAN: INFLUENT		19.1	11.6	8.75	8.5	78.4	39.8	28.3	1.619	1.013	0.258	0.004	0.033
EFFLUENT		20.2	6.8	7.70	1.5	23.5	6.2	1.6	0.881	0.904	0.096	0.046	3.154
PERCENT REMOVAL:		-5.	42.	12.	83.	70.	84.	94.	46.	11.	63.	-1200.	-9458.
18	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
20	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
26	0.6	16.8	8.0	7.78	2.0	21.0	9.3	1.3	1.151	1.028	0.423	0.054	2.853

(Continued)

TABLE A-1-3. (CONTINUED)

OCT 3	0.6	16.8	5.8	7.49	1.4	15.2	1.7	0.3	1.925	1.866	0.588	0.044	4.010
10	0.6	14.8	6.8	7.70	0.7	14.1	2.0	0.5	4.897	2.239	0.559	0.204	6.474
17	0.6	13.5	4.9	7.60	2.0	10.4	2.7	0.6	2.289	1.955	0.315	0.076	3.501
RUN NUMBER 4 - 9/26-10/22													
MEAN: INFLUENT		14.4	8.3	8.32	7.1	33.4	22.8	9.5	3.106	2.038	3.150	0.020	0.069
EFFLUENT		15.5	6.4	7.64	1.5	15.2	3.9	0.7	2.566	1.772	0.471	0.095	4.212
PERCENT REMOVAL:		-7.	23.	8.	79.	55.	83.	93.	17.	13.	85.	-367.	-6027.
24	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
31	0.6	-5.0	-5.0	-5.00	-5.0	-5.0	-5.0	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
NOV 7	0.6	8.3	7.7	7.91	0.8	11.9	3.1	1.4	2.313	2.238	0.551	0.163	5.894
14	0.6	6.8	8.0	7.36	1.4	14.6	1.9	1.1	2.311	2.317	2.434	0.237	2.423
RUN NUMBER 5 - 10/31-11/16													
MEAN: INFLUENT		7.5	9.7	8.36	18.0	43.0	33.4	24.3	2.676	2.104	3.786	0.040	0.159
EFFLUENT		7.6	7.9	7.64	1.1	13.3	2.5	1.3	2.312	2.278	1.493	0.200	4.159
PERCENT REMOVAL:		-1.	19.	9.	94.	69.	93.	95.	14.	-8.	61.	-396.	-2532.
21	0.6	6.3	7.6	7.80	1.6	13.8	2.5	1.2	2.208	2.165	0.908	0.540	9.541
26	0.6	4.0	7.8	7.70	1.8	13.2	2.7	1.2	2.719	2.530	1.314	0.010	2.121
RUN NUMBER 6 - 11/20-12/4													
MEAN: INFLUENT		4.6	10.8	8.51	11.0	35.5	27.8	14.9	2.480	2.262	4.934	0.027	0.108
EFFLUENT		5.2	7.7	7.75	1.7	13.5	2.6	1.2	2.464	2.348	1.061	0.275	5.831
PERCENT REMOVAL:		-12.	29.	9.	85.	62.	91.	92.	1.	-4.	78.	-919.	-5324.
DEC 5	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
12	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
19	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
26	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
JAN 2	0.4	1.2	10.6	7.63	6.0	23.1	4.8	3.5	2.851	2.681	2.240	0.092	5.136
9	0.4	1.0	7.2	7.92	2.1	16.6	4.2	1.2	2.906	2.863	3.168	0.072	3.845
16	0.4	1.2	7.2	7.71	5.7	24.6	5.2	0.7	3.287	3.025	5.992	0.016	0.244
23	0.4	1.5	7.7	7.98	10.4	30.0	5.2	3.5	3.513	3.361	7.061	0.012	0.806
30	0.4	1.5	7.0	7.88	9.4	35.7	10.8	8.1	3.541	3.096	6.622	0.016	0.078
FEB 6	0.4	0.5	7.1	7.64	9.0	38.4	8.7	7.1	3.513	3.240	5.911	0.015	0.105
13	0.4	-5.0	5.6	7.96	13.5	50.6	18.3	14.8	3.420	2.766	6.068	0.018	0.058
20	0.4	2.9	10.8	7.90	13.0	32.2	12.0	10.8	2.758	2.727	4.129	0.026	0.078
27	0.4	3.7	8.0	7.92	9.5	39.9	11.5	10.5	3.008	2.611	4.602	0.025	0.271
MAR 6	0.4	5.5	8.2	8.07	15.3	44.7	10.8	9.8	5.136	2.606	4.822	0.056	0.123
13	0.4	5.3	6.4	7.79	9.2	28.1	9.2	8.3	2.756	2.367	1.413	0.058	0.694
20	0.4	6.0	7.4	7.98	9.9	34.3	14.6	13.2	2.600	2.538	3.285	0.041	0.933

(Continued)

TABLE A-1-3. (CONTINUED)

RUN NUMBER 7 - 1/1-3/21													
MEAN: INFLUENT		3.4	9.6	8.55	18.0	63.9	29.1	26.4	3.517	2.891	5.076	0.016	0.075
EFFLUENT		2.8	7.8	7.87	9.4	33.2	9.6	7.6	3.274	2.840	4.609	0.037	1.031
PERCENT REMOVAL:		18.	19.	8.	48.	48.	67.	71.	7.	2.	9.	-138.	-1284.
27	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
APR 3	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
10	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
17	0.6	7.2	5.8	7.18	5.0	17.3	3.5	1.9	1.906	1.300	0.690	0.144	9.657
24	0.6	11.1	6.8	7.60	5.7	16.3	2.8	1.7	2.640	2.529	0.894	0.182	7.722
RUN NUMBER 8 - 4/15-4/29													
MEAN: INFLUENT		8.4	5.5	8.02	18.0	52.6	23.4	11.7	3.234	2.678	4.297	0.047	0.175
EFFLUENT		9.2	6.3	7.39	5.3	16.8	3.2	1.8	2.273	1.915	0.792	0.163	8.690
PERCENT REMOVAL:		-9.	-15.	8.	70.	68.	87.	85.	30.	28.	82.	-247.	-4865.
MAY 1	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
8	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
15	0.6	15.4	7.9	7.30	2.3	16.9	3.3	1.9	2.229	2.262	0.225	0.033	4.933
22	0.6	13.0	6.3	7.80	1.4	11.6	1.9	0.5	1.522	1.412	0.163	0.013	3.064
29	0.6	16.0	6.0	7.50	1.8	18.2	2.1	1.0	3.611	3.559	0.244	0.107	4.909
JUN 5	0.6	17.0	3.8	7.52	6.2	29.2	2.6	1.6	2.835	2.506	1.252	0.098	0.403
RUN NUMBER 9 - 5/14-6/8													
MEAN: INFLUENT		14.6	6.0	8.68	88.0	165.9	61.4	49.2	3.579	2.201	1.758	0.074	0.358
EFFLUENT		15.4	6.0	7.53	2.9	19.0	2.5	1.3	2.549	2.435	0.471	0.063	3.327
PERCENT REMOVAL:		-5.	1.	13.	97.	89.	96.	97.	29.	-11.	73.	15.	-829.

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE A-1-4. EFFLUENT QUALITY AND RUN SUMMARY FOR FILTER 3

FILTER [illegible] DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
JUL 2	1.0	-5.0	-5.0	-5.00	2.6	39.0	2.3	0.5	2.750	3.091	1.171	0.796	1.779
12	0.8	22.5	7.1	7.90	4.0	56.8	11.9	1.3	2.049	1.697	0.156	0.227	3.198
15	0.8	-5.0	-5.0	-5.00	-5.0	-5.0	2.9	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
17	0.8	27.0	5.1	-5.00	1.7	5.0	17.8	0.8	-5.000	1.464	0.518	0.052	9.425
18	0.8	-5.0	-5.0	-5.00	-5.0	-5.0	12.3	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
19	0.8	-5.0	-5.0	-5.00	-5.0	-5.0	28.1	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
22	0.8	-5.0	-5.0	-5.00	-5.0	-5.0	3.8	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
24	0.8	25.7	5.8	7.88	2.1	77.4	3.8	0.6	1.794	1.802	0.120	0.015	1.701
26	0.8	-5.0	-5.0	-5.00	-5.0	-5.0	2.1	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
31	0.8	24.7	4.7	7.78	2.8	23.2	2.3	1.1	1.747	1.769	0.490	0.066	3.165
RUN NUMBER 1 - 7/2-7/31													
MEAN: INFLUENT		22.8	2.6	8.73	7.6	64.2	12.4	8.4	2.490	2.203	2.897	0.054	0.236
EFFLUENT		25.0	5.7	7.85	2.6	40.3	8.7	0.9	2.085	1.965	0.491	0.231	3.714
PERCENT REMOVAL:		-10.	-122.	10.	65.	37.	30.	90.	16.	11.	83.	-330.	-1475.
AUG 6	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
7	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
14	0.8	20.9	8.0	8.15	3.0	27.8	16.3	5.6	1.481	1.259	0.092	0.009	2.130
16	0.8	-5.0	-5.0	-5.00	-5.0	-5.0	7.0	5.1	-5.000	-5.000	-5.000	-5.000	-5.000
19	0.8	-5.0	-5.0	-5.00	-5.0	-5.0	5.3	2.9	-5.000	-5.000	-5.000	-5.000	-5.000
RUN NUMBER 2 - 8/14-8/20													
MEAN: INFLUENT		19.9	10.9	9.20	12.9	84.8	54.3	41.4	1.807	0.985	0.168	0.007	0.043
EFFLUENT		20.9	8.0	8.15	3.0	27.8	9.5	4.5	1.481	1.259	0.092	0.009	2.130
PERCENT REMOVAL:		-5.	27.	11.	77.	67.	82.	89.	18.	-28.	45.	-29.	-4853.
21	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
SEP 4	0.8	20.1	7.3	7.70	1.5	29.3	11.7	3.6	0.939	1.022	0.072	0.035	1.089
6	0.8	-5.0	-5.0	-5.00	-5.0	-5.0	5.2	3.1	-5.000	-5.000	-5.000	-5.000	-5.000
9	0.8	-5.0	-5.0	-5.00	0.8	-5.0	3.3	1.3	-5.000	-5.000	-5.000	-5.000	-5.000
11	0.8	20.0	6.0	7.80	0.9	14.4	2.6	1.2	0.811	1.136	0.030	0.020	1.469
RUN NUMBER 3 - 9/4-9/12													
MEAN: INFLUENT		19.1	11.6	8.75	8.5	78.4	39.8	28.3	1.619	1.013	0.258	0.004	0.033
EFFLUENT		20.1	6.7	7.75	1.1	21.9	5.7	2.3	0.875	1.079	0.051	0.028	1.279
PERCENT REMOVAL:		-5.	42.	11.	88.	72.	86.	92.	46.	-7.	80.	-686.	-3776.
18	0.8	16.9	7.8	7.40	2.2	25.8	5.7	1.3	0.866	0.799	0.063	0.172	2.347
20	0.8	-5.0	-5.0	-5.00	0.8	-5.0	2.1	0.0	-5.000	-5.000	-5.000	-5.000	-5.000
26	0.8	18.0	6.2	7.89	0.8	11.2	1.4	0.3	1.323	1.378	0.054	0.038	2.484
OCT 3	0.8	16.0	4.7	7.58	0.8	16.7	2.0	0.5	2.103	2.014	0.310	0.069	3.627

(Continued)

TABLE A-1-4. (CONTINUED)

RUN NUMBER 4 - 9/18-10/6													
MEAN: INFLUENT		16.3	9.7	8.42	6.2	32.9	16.8	8.5	2.022	1.757	2.560	0.015	0.047
EFFLUENT		17.0	6.2	7.62	1.2	17.9	2.8	0.5	1.431	1.397	0.142	0.093	2.819
PERCENT REMOVAL:		-4.	36.	9.	81.	46.	83.	94.	29.	20.	94.	-507.	-5941.
10	0.8	15.2	6.0	7.50	1.7	14.3	1.5	0.7	5.076	2.463	0.374	0.106	5.857
17	0.8	14.9	5.6	7.60	3.3	9.5	2.2	0.4	2.253	2.210	0.081	0.040	5.671
RUN NUMBER 5 - 10/9-10/21													
MEAN: INFLUENT		12.9	9.5	8.37	9.1	35.9	26.0	10.2	3.892	2.012	2.869	0.026	0.104
EFFLUENT		15.1	5.8	7.55	2.5	11.9	1.9	0.6	3.665	2.337	0.228	0.073	5.764
PERCENT REMOVAL:		-17.	39.	10.	72.	67.	93.	95.	6.	-16.	92.	-181.	-5469.

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE A-1-5. EFFLUENT QUALITY AND RUN SUMMARY FOR FILTER 4

FILTER 4 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
JUL 2	1.3	-5.0	-5.0	0.00	3.4	23.0	3.0	1.1	2.769	3.096	1.150	0.747	1.830
12	1.0	21.5	6.8	8.10	4.6	31.9	11.1	1.3	2.011	1.665	0.392	0.399	1.189
15	1.0	-5.0	-5.0	-5.00	-5.0	-5.0	7.9	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
17	1.0	27.0	4.0	-5.00	2.0	61.0	18.5	1.1	-5.000	1.536	0.725	0.074	8.490
18	1.0	-5.0	-5.0	-5.00	-5.0	-5.0	6.1	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
19	1.0	-5.0	-5.0	-5.00	-5.0	-5.0	15.6	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
22	1.0	-5.0	-5.0	-5.00	-5.0	-5.0	6.2	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
24	1.0	25.7	4.1	8.02	1.8	26.6	4.1	0.6	1.941	1.824	0.340	0.008	1.312
26	1.0	-5.0	-5.0	-5.00	-5.0	-5.0	3.3	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
RUN NUMBER 1 - 7/2-7/29													
MEAN: INFLUENT		22.8	2.4	8.82	5.9	66.6	11.9	7.6	2.549	2.235	2.996	0.061	0.281
EFFLUENT		24.7	5.0	5.37	3.0	35.6	8.4	1.0	2.240	2.030	0.652	0.307	3.205
PERCENT REMOVAL:		-9.	-111.	39.	50.	46.	29.	86.	12.	9.	78.	-407.	-1040.
31	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
AUG 6	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
7	P	-1.0	-1.0	-1.00	0.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
14	1.0	20.7	7.9	8.11	3.4	35.1	15.2	5.3	1.422	1.222	0.073	0.004	1.067
RUN NUMBER 2 - 8/14-8/16													
MEAN: INFLUENT		19.9	10.9	9.20	12.9	84.8	55.7	44.3	1.807	0.985	0.168	0.007	0.043
EFFLUENT		20.7	7.9	8.11	3.4	35.1	15.2	5.3	1.422	1.222	0.073	0.004	1.067
PERCENT REMOVAL:		-4.	28.	12.	74.	59.	73.	88.	21.	-24.	57.	43.	-2381.
16	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
19	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
21	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
SEP 4	1.0	20.0	7.1	7.90	1.7	29.2	14.6	6.5	1.061	1.045	0.096	0.036	2.567
6	1.0	-5.0	-5.0	-5.00	-5.0	-5.0	4.4	1.6	-5.000	-5.000	-5.000	-5.000	-5.000
RUN NUMBER 3 - 9/4-9/7													
MEAN: INFLUENT		19.2	12.5	8.80	8.8	91.3	47.1	33.1	1.721	0.954	0.120	0.001	0.020
EFFLUENT		20.0	7.1	7.90	1.7	29.2	9.5	4.0	1.061	1.045	0.096	0.036	2.567
PERCENT REMOVAL:		-4.	43.	10.	81.	68.	80.	88.	38.	-10.	20.	-3500.	-12735.
9	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
11	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
18	1.0	-5.0	-5.0	-5.00	2.9	25.8	9.5	2.8	0.964	1.048	-1.000	-1.000	-1.000
20	1.0	-5.0	-5.0	-5.00	-5.0	-5.0	-5.0	-5.0	-5.000	-5.000	-5.000	0.084	1.966
26	1.0	15.8	5.7	7.66	1.4	19.7	1.2	0.1	1.411	1.559	0.529	0.401	4.653

(Continued)

TABLE A-1-5. (CONTINUED)

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RUN NUMBER  4 - 9/18-9/27
    MEAN: INFLUENT  17.0   10.9   8.54   6.1   32.5   16.8    9.3   1.789   1.524   1.540   0.016   0.055
          EFFLUENT  15.8    5.7   7.66   2.2   22.8    5.3    1.5   1.188   1.303   0.529   0.243   3.310
PERCENT REMOVAL:      7.    48.    10.   65.    30.    68.    84.     34.     14.     66.  -1465.  -5972.

OCT 3       1.0     16.1    6.4   7.54   1.0   15.6    2.3    0.5   2.296   2.132   0.160   0.093   2.728

RUN NUMBER  5 - 10/2-10/6
    MEAN: INFLUENT  15.1    7.2   8.18   6.4   33.8   16.5    6.0   2.488   2.222   4.602   0.015   0.031
          EFFLUENT  16.1    6.4   7.54   1.0   15.6    2.3    0.5   2.296   2.132   0.160   0.093   2.728
PERCENT REMOVAL:     -7.    11.     8.   84.    54.    86.    92.      8.      4.     97.   -520.  -8700.

  10        1.0     14.8    6.7   7.70   1.2   17.1    2.0    0.9   5.028   2.448   0.311   0.168   3.518

RUN NUMBER  6 - 10/9-10/13

    MEAN: INFLUENT  13.9    8.3   8.34   7.7   36.4   23.1   11.4   5.387   1.933   3.832   0.013   0.067
          EFFLUENT  14.8    6.7   7.70   1.2   17.1    2.0    0.9   5.028   2.448   0.311   0.168   3.518
PERCENT REMOVAL:     -6.    19.     8.   84.    53.    91.    92.      7.    -27.     92.  -1192.  -5151.

  17         P      -1.0   -1.0  -1.00  -1.0   -1.0   -1.0   -1.0  -1.000  -1.000  -1.000  -1.000  -1.000
  24        1.0     12.0    7.5   7.70   1.2   15.2    2.4    1.1   2.431   2.057   0.087   0.065   3.877

RUN NUMBER  7 - 10/23-10/28
    MEAN: INFLUENT  11.9    8.1   8.40  19.3   66.2   43.5   33.5   2.714   1.880   2.516   0.055   0.052
          EFFLUENT  12.0    7.5   7.70   1.2   15.2    2.4    1.1   2.431   2.057   0.087   0.065   3.877
PERCENT REMOVAL:     -1.     7.     8.   94.    77.    94.    97.     10.     -9.     97.    -18.  -7356.

  31         P      -1.0   -1.0  -1.00  -1.0   -1.0   -1.0   -1.0  -1.000  -1.000  -1.000  -1.000  -1.000
NOV 7        P      -1.0   -1.0  -1.00  -1.0   -1.0   -1.0   -1.0  -1.000  -1.000  -1.000  -1.000  -1.000
  14        1.0      7.3    9.0   7.69   1.2   14.9    2.4    0.7   2.044   2.129   0.264   0.214   6.110

RUN NUMBER  8 - 11/13-11/20
    MEAN: INFLUENT   5.8   12.9   8.72  19.9   53.0   40.8   29.5   2.637   2.173   2.693   0.037   0.196
          EFFLUENT   7.3    9.0   7.69   1.2   14.9    2.4    0.7   2.044   2.129   0.264   0.214   6.110
PERCENT REMOVAL:    -26.    30.    12.   94.    72.    94.    98.     22.      2.     90.   -476.  -3017.

  21         P      -1.0   -1.0  -1.00  -1.0   -1.0   -1.0   -1.0  -1.000  -1.000  -1.000  -1.000  -1.000
  26         P      -1.0   -1.0  -1.00  -1.0   -1.0   -1.0   -1.0  -1.000  -1.000  -1.000  -1.000  -1.000
DEC 5        P      -1.0   -1.0  -1.00  -1.0   -1.0   -1.0   -1.0  -1.000  -1.000  -1.000  -1.000  -1.000
  12         P      -1.0   -1.0  -1.00  -1.0   -1.0   -1.0   -1.0  -1.000  -1.000  -1.000  -1.000  -1.000
  19         P      -1.0   -1.0  -1.00  -1.0   -1.0   -1.0   -1.0  -1.000  -1.000  -1.000  -1.000  -1.000
  26        0.4      1.8   13.2   8.05   2.5   18.4    2.6    0.9   2.658   2.501   2.710   0.106   3.230
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(Continued)

TABLE A-1-5. (CONTINUED)

JAN 2	0.4	1.1	8.8	7.58	2.2	11.0	2.4	1.1	3.218	2.759	2.257	0.275	4.095
9	0.4	1.2	8.1	7.82	2.3	13.4	1.9	1.0	2.748	2.676	2.703	0.590	6.786
16	0.4	1.0	6.6	7.41	2.6	17.0	2.6	0.0	2.996	2.982	4.073	0.133	3.933
23	0.4	2.0	8.8	7.50	3.3	15.5	2.[illegible]	1.7	3.513	3.422	3.084	0.202	6.612
30	0.4	1.0	7.3	7.61	7.1	26.5	8.0	7.2	3.719	3.081	3.189	0.030	3.378
FEB 6	0.4	2.0	9.4	7.68	11.8	31.2	9.9	9.0	3.529	3.361	2.373	0.021	3.517
13	0.4	3.0	8.0	7.52	3.1	19.9	5.6	4.8	3.480	3.152	0.699	0.197	10.431
20	0.4	2.7	9.3	7.60	2.2	15.2	4.9	4.1	3.015	2.955	0.473	0.010	6.530
27	0.4	2.1	7.1	7.52	3.1	22.9	6.1	4.6	3.573	3.176	0.362	0.029	9.578
MAR 6	0.4	5.0	8.8	7.85	2.9	14.8	3.7	3.3	6.667	5.227	0.238	0.015	4.285
13	0.4	5.9	7.6	7.61	4.1	28.7	6.3	5.8	3.161	2.831	0.433	0.015	2.042
20	0.4	6.0	8.7	7.79	5.2	19.8	9.2	7.3	2.892	2.800	0.506	0.012	1.424
27	0.4	4.0	8.6	7.72	2.7	21.7	7.8	6.7	2.974	2.773	0.708	0.019	1.358
APR 3	0.4	5.2	7.3	7.61	2.5	17.2	4.4	3.5	2.748	2.715	0.213	0.012	1.412
10	0.4	6.6	8.5	7.15	2.4	18.2	3.2	2.5	2.954	2.569	0.517	0.017	1.661
17	0.4	6.0	8.3	7.41	2.7	21.9	3.1	2.0	2.796	2.412	1.081	0.040	2.010
24	0.4	11.0	7.9	7.60	2.8	18.5	2.8	1.7	2.688	2.513	1.085	0.052	2.162
MAY 1	0.4	11.0	7.9	7.47	1.8	15.2	2.1	1.8	2.770	2.689	0.346	0.046	2.270
8	0.4	9.0	-5.0	7.80	2.1	17.3	3.1	2.3	2.608	2.480	0.275	0.042	1.888
RUN NUMBER 9 - 12/23-5/14													
MEAN: INFLUENT		4.7	9.4	8.52	17.5	64.2	30.8	25.3	3.358	2.750	4.543	0.029	0.136
EFFLUENT		4.4	8.4	7.62	3.5	19.0	4.6	3.6	3.235	2.954	1.366	0.093	3.930
PERCENT REMOVAL:		6.	10.	11.	80.	70.	85.	86.	4.	-7.	70.	-226.	-2792.

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE A-1-6. EFFLUENT QUALITY AND RUN SUMMARY FOR FILTER 5

FILTER 5 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
JUL 2	1.5	-5.0	-5.0	-5.00	2.7	19.0	2.2	0.7	3.173	3.192	1.378	0.790	0.718
12	1.2	21.5	6.4	8.00	4.5	26.1	6.9	1.7	1.911	1.854	0.262	0.303	1.167
15	1.2	-5.0	-5.0	-5.00	-5.0	-5.0	17.9	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
17	1.2	25.0	4.7	-5.00	6.0	87.0	17.6	0.4	-5.000	1.536	0.665	0.133	7.027
18	1.2	-5.0	-5.0	-5.00	-5.0	-5.0	5.9	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
19	1.2	-5.0	-5.0	-5.00	-5.0	-5.0	10.0	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
22	1.2	-5.0	-5.0	-5.00	-5.0	-5.0	3.7	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
24	1.2	25.5	3.3	8.23	2.4	31.6	1.1	0.0	1.641	1.581	0.697	0.025	1.955
RUN NUMBER 1 - 7/2-7/24													
MEAN: INFLUENT		22.8	2.4	8.82	5.9	66.6	10.5	7.6	2.549	2.235	2.996	0.061	0.281
EFFLUENT		24.0	4.8	8.12	3.9	40.9	8.2	0.7	2.242	2.041	0.751	0.313	2.717
PERCENT REMOVAL:		-5.	-104.	8.	34.	39.	22.	91.	12.	9.	75.	-417.	-866.
26	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
31	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
AUG 6	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
7	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
14	1.2	20.1	8.2	8.11	2.7	30.6	12.4	5.4	1.410	1.222	0.130	0.019	1.402
RUN NUMBER 2 - 8/14-8/16													
MEAN: INFLUENT		19.9	10.9	9.20	12.9	84.8	55.7	44.3	1.807	0.985	0.168	0.007	0.043
EFFLUENT		20.1	8.2	8.11	2.7	30.6	12.4	5.4	1.410	1.222	0.130	0.019	1.402
PERCENT REMOVAL:		-1.	25.	12.	79.	64.	78.	88.	22.	-24.	23.	-171.	-3160.
16	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
19	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
21	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
SEP 4	1.0	21.5	7.2	8.00	-5.0	26.5	9.9	2.7	1.054	-5.000	0.152	-5.000	4.899
6	1.0	-5.0	-5.0	-5.00	-5.0	-5.0	2.9	1.2	-5.000	-5.000	-5.000	-5.000	-5.000
9	1.0	-5.0	-5.0	-5.00	2.5	-5.0	4.3	1.5	-5.000	-5.000	-5.000	-5.000	-5.000
11	1.0	-5.0	-5.0	-5.00	2.9	20.0	2.1	1.5	1.164	0.971	0.111	0.108	2.761
RUN NUMBER 3 - 9/4-9/12													
MEAN: INFLUENT		19.1	11.6	8.75	8.5	78.4	39.8	28.3	1.619	1.013	0.258	0.004	0.033
EFFLUENT		21.5	7.2	8.00	2.7	23.3	4.8	1.7	1.109	0.971	0.132	0.108	3.830
PERCENT REMOVAL:		-13.	38.	9.	68.	70.	88.	94.	32.	4.	49.	-2986.	-11505.
18	1.0	16.7	7.7	7.40	2.1	26.4	6.1	0.9	1.103	1.118	0.068	0.174	2.836
20	1.0	-5.0	-5.0	-5.00	0.7	-5.0	3.0	0.7	-5.000	-5.000	-5.000	-5.000	-5.000
26	1.0	17.1	5.8	7.90	0.8	16.9	1.2	0.5	1.505	1.496	0.145	0.048	3.111

(Continued)

TABLE A-1-6. (CONTINUED)

RUN NUMBER 4 - 9/18-9/27													
MEAN: INFLUENT		17.0	10.9	8.54	6.1	32.5	16.8	9.3	1.789	1.524	1.540	0.016	0.055
EFFLUENT		16.9	6.8	7.65	1.2	22.7	3.4	0.7	1.304	1.307	0.107	0.111	2.974
PERCENT REMOVAL:		0.	38.	10.	80.	30.	80.	92.	27.	14.	93.	-616.	-5356.
OCT 3	1.0	16.5	5.8	7.55	1.0	12.3	1.7	0.6	2.280	2.207	0.575	0.162	3.934
RUN NUMBER 5 - 10/2-10/6													
MEAN: INFLUENT		15.1	7.2	8.18	6.4	33.8	16.5	6.0	2.488	2.222	4.602	0.015	0.031
EFFLUENT		16.5	5.8	7.55	1.0	12.3	1.7	0.6	2.280	2.207	0.575	0.162	3.934
PERCENT REMOVAL:		-9.	19.	8.	84.	64.	90.	90.	8.	1.	88.	-980.	-12590.
10	1.0	14.6	3.3	7.59	1.7	16.5	1.9	0.7	5.148	2.500	0.374	0.451	5.532
RUN NUMBER 6 - 10/9-10/13													
MEAN: INFLUENT		13.9	8.3	8.34	7.7	36.4	23.1	11.4	5.387	1.933	3.932	0.013	0.067
EFFLUENT		14.6	3.3	7.59	1.7	16.5	1.8	0.7	5.148	2.500	0.374	0.451	5.532
PERCENT REMOVAL:		-5.	60.	9.	78.	55.	92.	94.	4.	-29.	90.	-3369.	-8157.
17	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
24	1.0	12.0	5.4	7.58	1.3	10.7	1.8	1.2	2.510	2.084	0.097	0.117	4.737
RUN NUMBER 7 - 10/22-10/28													
MEAN: INFLUENT		11.9	8.1	8.40	19.3	66.2	43.5	33.5	2.714	1.880	2.516	0.055	0.052
EFFLUENT		12.0	5.4	7.58	1.3	10.7	1.8	1.2	2.510	2.084	0.097	0.117	4.737
PERCENT REMOVAL:		-1.	33.	10.	93.	84.	96.	96.	8.	-11.	96.	-113.	-9010.
31	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
NOV 7	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
14	1.0	7.8	8.7	7.58	1.3	12.6	2.0	0.6	2.000	2.043	0.360	0.461	11.071
RUN NUMBER 8 - 11/13-11/15													
MEAN: INFLUENT		5.8	12.9	8.72	19.9	53.0	40.8	29.5	2.637	2.173	2.693	0.037	0.196
EFFLUENT		7.8	8.7	7.58	1.3	12.6	2.0	0.6	2.000	2.043	0.360	0.461	11.071
PERCENT REMOVAL:		-34.	33.	13.	93.	76.	95.	98.	24.	6.	87.	-1146.	-5548.
21	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
26	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
DEC 5	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
12	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
19	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
26	0.4	2.0	12.4	8.03	1.6	17.1	1.6	0.9	2.950	2.811	2.436	0.040	3.232

(Continued)

TABLE A-1-6. (CONTINUED)

JAN 2	0.4	1.0	9.8	8.49	1.6	16.3	1.3	0.7	3.157	2.728	2.531	0.055	3.788
9	0.4	1.2	7.9	7.78	1.9	14.3	2.0	1.2	2.719	2.691	2.550	0.510	2.714
16	0.4	1.0	5.3	7.36	2.1	14.8	1.5	0.5	3.084	2.909	3.749	0.229	5.884
23	0.4	1.9	7.7	7.52	1.9	15.1	2.2	1.5	3.634	3.574	3.101	0.057	5.604
30	0.4	1.5	9.8	7.65	4.2	24.5	3.9	3.3	3.360	3.481	2.694	0.028	3.455
FEB 6	0.4	1.8	8.2	7.39	3.8	20.3	4.3	3.8	3.924	3.513	1.754	0.010	2.509
13	0.4	3.2	8.4	7.62	5.3	24.1	6.1	5.6	3.554	3.123	2.595	0.059	1.125
RUN NUMBER 9 - 12/23-2/18													
MEAN: INFLUENT		2.4	6.0	8.30	15.7	54.8	18.9	16.7	3.500	3.098	5.752	0.018	0.076
EFFLUENT		1.7	8.7	7.73	2.8	18.3	2.9	2.2	3.298	3.104	2.676	0.124	3.539
PERCENT REMOVAL:		30.	-44.	7.	82.	67.	85.	87.	6.	-0.	53.	-591.	-4587.
20	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0						
27	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
MAR 6	0.4	4.1	9.5	7.71	1.9	19.9	6.3	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
13	0.4	5.9	6.8	7.51	1.6	16.0	3.8	5.5	6.439	3.182	0.201	0.026	5.153
20	0.4	6.5	8.5	7.65	2.9	15.1	3.8	3.4	3.206	2.951	0.054	0.004	1.242
								2.9	2.877	2.892	0.153	0.003	0.580
RUN NUMBER 10 - 3/5-3/24													
MEAN: INFLUENT		5.4	13.4	9.07	19.4	82.7	45.7	40.8	3.252	2.434	4.263	0.019	0.114
EFFLUENT		5.5	8.3	7.62	2.1	17.0	4.6	3.9	4.174	3.008	0.136	0.011	2.325
PERCENT REMOVAL:		-2.	38.	16.	89.	79.	90.	90.	-28.	-24.	97.	42.	-1939.
27	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
APR 3	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
10	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
17	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
24	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
MAY 1	1.0	10.4	7.4	7.43	2.4	24.5	3.0	1.9	3.331	3.164	0.092	0.014	5.137
RUN NUMBER 11 - 4/29-5/5													
MEAN: INFLUENT		10.5	12.0	8.56	10.2	55.2	32.4	22.3	3.032	2.689	2.811	0.069	0.283
EFFLUENT		10.4	7.4	7.43	2.4	24.5	3.0	1.9	3.331	3.164	0.092	0.014	5.137
PERCENT REMOVAL:		1.	38.	13.	76.	56.	91.	91.	-10.	-18.	97.	80.	-1715.
8	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
15	1.0	17.8	5.2	7.40	1.8	15.0	2.7	1.8	2.639	2.656	0.221	0.059	7.813
22	1.0	13.5	6.5	7.90	2.2	19.4	1.6	0.7	1.647	1.616	0.275	0.091	1.741
RUN NUMBER 12 - 5/14-5/26													
MEAN: INFLUENT		12.8	9.5	8.90	7.9	41.0	13.9	9.4	2.177	1.657	1.432	0.083	0.487
EFFLUENT		15.7	5.8	7.65	2.0	17.2	2.2	1.3	2.143	2.136	0.248	0.075	4.777
PERCENT REMOVAL:		-22.	38.	14.	75.	58.	85.	87.	2.	-29.	83.	10.	-882.

(Continued)

TABLE A-1-6. (CONTINUED)

29	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.00C	-1.000	-1.000	-1.000	-1.000
JUN 5	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
12	1.0	20.7	5.3	7.62	1.4	23.0	3.1	0.8	2.774	2.615	0.062	0.015	5.238
RUN NUMBER 13 - 6/10-6/16													
MEAN: INFLUENT		18.0	2.8	8.28	8.5	38.6	19.9	15.6	3.080	2.428	3.296	0.013	0.037
EFFLUENT		20.7	5.3	7.62	1.4	23.0	3.1	0.8	2.774	2.615	0.062	0.015	5.238
PERCENT REMOVAL:		-15.	-89.	8.	84.	40.	84.	95.	10.	-8.	98.	-15.	-14057.

* NOTE: -1.) INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE A-1-7. EFFLUENT QUALITY AND RUN SUMMARY FOR FILTER 6

FILTER 6 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
JUL 2	2.0	22.0	6.4	7.80	2.1	30.0	2.4	0.4	3.000	3.404	0.224	0.092	3.676
RUN NUMBER 1 -		7/2-7/7											
MEAN: INFLUENT		21.0	2.2	8.80	3.5	37.0	10.9	2.6	3.330	3.192	3.370	0.174	0.784
EFFLUENT		22.0	6.4	7.80	2.1	30.0	2.4	0.4	3.000	3.404	0.224	0.092	3.676
PERCENT REMOVAL:		-5.	-191.	11.	40.	19.	78.	85.	10.	-7.	93.	47.	-369.
12	0.2	22.0	6.4	7.80	2.2	26.1	34.6	2.0	2.099	1.848	0.452	0.063	7.978
15	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	3.2	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
17	0.2	24.0	6.2	-5.00	6.0	44.0	8.2	0.0	-5.000	1.714	0.040	0.124	12.512
18	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	19.6	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
19	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	17.4	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
22	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	2.7	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
24	0.2	25.1	6.1	8.10	0.9	88.3	2.2	0.0	1.641	1.640	0.121	0.022	3.509
26	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	2.2	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
31	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	-5.0	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
AUG 6	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	-5.0	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
7	0.2	23.2	6.1	8.00	1.7	9.8	5.1	2.9	1.528	1.576	0.052	0.124	2.524
14	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	-5.0	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
16	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	-5.0	-5.0	-5.000	-5.000	-5.000	-5.000	-5.000
19	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	1.6	0.9	-5.000	-5.000	-5.000	-5.000	-5.000
21	0.2	21.0	6.8	7.93	0.5	8.3	2.4	1.2	1.222	1.229	0.044	0.004	1.032
RUN NUMBER 2 -		7/12-8/22											
MEAN: INFLUENT		22.0	5.4	8.89	8.5	73.1	29.6	25.7	2.005	1.546	1.801	0.019	0.091
EFFLUENT		23.1	6.3	7.96	2.3	35.3	9.0	1.2	1.623	1.601	0.142	0.067	5.511
PERCENT REMOVAL:		-5.	-17.	10.	74.	52.	70.	95.	19.	-4.	92.	-255.	-5947.
SEP 4	0.2	20.5	7.3	7.60	1.0	28.1	6.6	2.2	1.315	1.272	0.064	0.032	6.870
6	0.2	-5.0	-5.0	-5.00	-5.0	-5.0	2.1	0.4	-5.000	-5.000	-5.000	-5.000	-5.000
9	0.2	-5.0	-5.0	-5.00	0.9	-5.0	2.5	1.5	-5.000	-5.000	-5.000	-5.000	-5.000
11	0.2	16.5	7.4	7.60	1.4	18.8	1.7	0.6	1.087	1.079	0.025	0.157	2.313
18	0.2	16.9	8.2	7.50	1.2	19.2	2.3	0.6	0.951	0.951	0.020	0.190	3.013
20	0.2	-5.0	-5.0	-5.00	0.9	-5.0	2.0	0.2	-5.000	-5.000	-5.000	-5.000	-5.000
26	0.2	15.9	8.5	7.80	0.8	18.9	1.5	0.4	1.505	1.189	0.045	0.016	4.664
OCT 3	0.2	14.7	7.4	7.65	2.2	12.3	1.5	0.4	1.841	1.792	0.036	0.000	5.888
10	0.2	13.9	8.1	7.76	1.0	12.7	2.7	0.6	4.658	2.321	0.040	0.032	6.009
17	0.2	12.5	7.4	7.60	1.0	10.3	2.3	0.3	2.301	2.330	0.071	0.017	5.877
24	0.2	11.9	7.8	7.63	0.8	10.0	1.6	0.5	1.685	2.035	0.048	0.005	5.396
31	0.2	10.1	7.7	7.61	1.4	7.0	2.3	0.4	2.069	2.070	0.066	0.027	5.103

(Continued)

TABLE A-1-7. (CONTINUED)

NOV 7	0.2	8.4	10.1	7.46	0.8	14.9	1.6	0.5	2.302	2.261	0.145	0.068	4.349
14	0.2	6.7	11.1	7.50	0.6	11.1	2.0	0.6	2.296	2.388	0.166	0.053	5.174
21	0.2	5.4	8.0	7.85	1.4	7.5	1.4	0.2	2.308	2.423	0.573	0.545	4.962
26	0.2	4.6	11.5	7.60	0.6	9.4	1.9	0.4	3.330	2.704	0.539	0.017	2.909
DEC 5	0.2	4.2	9.5	7.77	0.8	12.5	1.7	0.6	2.596	2.551	0.748	0.221	7.033
12	0.2	3.1	7.5	7.81	1.9	16.1	1.6	1.0	2.427	2.206	0.966	0.054	3.781
19	0.2	2.3	9.6	7.82	1.4	13.4	1.7	1.0	2.321	2.307	1.330	0.036	3.422
26	0.2	2.0	15.4	7.70	1.4	12.6	1.4	0.8	2.610	2.517	1.214	0.032	3.950
JAN 2	0.2	2.8	6.7	7.53	1.3	11.9	1.1	0.9	2.805	2.759	1.830	0.040	4.000
9	0.2	1.5	3.8	8.02	1.6	11.5	1.3	1.0	2.734	2.705	2.478	0.010	7.377
16	0.2	1.2	6.5	7.61	2.9	16.1	0.9	0.5	3.098	2.967	3.538	0.010	0.927
23	0.2	1.8	9.4	7.75	4.5	18.3	2.5	2.1	3.574	3.361	2.546	0.011	1.355
30	0.2	1.5	8.4	7.61	3.9	15.1	3.2	3.0	3.393	3.220	3.204	0.010	1.267
FEB 6	0.2	1.0	8.7	7.79	3.9	23.2	3.6	3.1	3.437	3.270	2.254	0.010	1.659
13	0.2	3.0	8.5	7.69	3.7	16.2	4.5	3.9	3.138	2.795	3.181	0.078	1.970
20	0.2	2.0	8.4	7.68	8.5	20.7	7.3	6.0	2.848	2.500	2.098	0.015	1.735
27	0.2	2.4	7.9	7.64	3.6	19.6	6.9	5.4	3.420	2.824	1.790	0.011	2.889
MAR 6	0.2	5.3	8.0	7.95	5.5	18.7	4.3	3.9	5.605	2.848	1.689	0.011	0.673
RUN NUMBER 3 - 9/4-3/11													
MEAN: INFLUENT		7.3	10.4	8.51	14.1	52.2	27.4	20.4	2.954	2.345	4.040	0.022	0.094
EFFLUENT		7.2	8.5	7.69	2.1	15.0	2.6	1.4	2.654	2.357	1.137	0.063	3.873
PERCENT REMOVAL:		2.	18.	10.	85.	71.	91.	93.	10.	-1.	72.	-181.	-4026.
13	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
20	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
27	P	-1.0	-1.0	-1.00	-1.0	-1.0	-1.0	-1.0	-1.000	-1.000	-1.000	-1.000	-1.000
APR 3	0.2	5.0	9.2	7.58	2.8	17.3	2.7	1.6	2.211	2.195	0.451	0.020	5.849
10	0.2	6.2	8.2	7.28	1.4	9.7	1.7	1.2	2.615	2.400	0.102	0.004	4.046
17	0.2	7.0	7.3	7.37	1.2	8.8	1.4	0.6	2.922	2.570	0.181	0.009	7.133
24	0.2	11.2	7.3	7.40	1.2	7.1	1.2	0.5	3.031	2.924	0.107	0.013	5.930
MAY 1	0.2	10.3	7.6	7.42	1.0	7.0	0.8	0.5	3.082	2.902	0.069	0.010	5.856
8	0.2	9.0	-5.0	7.50	0.6	7.0	1.2	0.5	2.704	2.672	0.069	0.003	4.097
15	0.2	15.6	8.6	7.40	0.7	9.3	2.1	0.7	2.377	2.328	0.072	0.014	8.864
22	0.2	12.0	7.1	7.60	0.9	9.1	2.2	0.5	2.087	2.055	0.120	0.003	3.843
29	0.2	15.6	7.0	7.40	0.7	16.8	2.1	1.1	3.851	3.559	0.040	0.005	5.538
JUN 5	0.2	16.6	6.6	7.35	0.8	10.4	2.8	0.5	2.420	2.417	0.052	0.006	6.628
12	0.2	17.6	6.8	7.55	0.7	14.2	3.6	0.6	2.682	2.661	0.115	0.015	7.123
19	0.2	16.8	6.7	7.60	1.0	6.2	3.0	0.4	2.514	3.043	0.040	0.010	8.342
26	0.2	17.0	8.6	7.25	0.7	10.3	6.8	0.5	3.754	3.456	0.022	0.013	6.671
RUN NUMBER 4 - 4/1-6/27													
MEAN: INFLUENT		12.2	5.7	8.39	36.5	90.7	38.6	28.1	3.260	2.470	2.677	0.052	0.239
EFFLUENT		12.3	7.6	7.44	1.1	10.2	2.4	0.7	2.788	2.706	0.111	0.010	6.148
PERCENT REMOVAL:		-1.	-34.	11.	97.	89.	94.	97.	14.	-10.	96.	81.	-2470.

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE A-2-1. SEASONAL SUMMARY FOR FILTER 1

FILTER 1 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
SUMMER : JUN 26-SEP 20													
MEAN: INFLUENT		20.6	6.7	8.61	7.8	64.6	23.6	16.9	2.192	1.833	2.158	0.036	0.150
EFFLUENT		22.0	6.6	7.75	1.7	24.1	5.3	1.1	1.577	1.446	0.435	0.161	4.363
PERCENT REMOVAL:		-7.	1.	10.	78.	63.	77.	94.	28.	21.	80.	-354.	-2816.
FALL : SEP 26-DEC 19													
MEAN: INFLUENT		8.2	10.8	8.54	13.6	42.1	27.8	17.7	2.755	2.102	3.547	0.031	0.120
EFFLUENT		9.0	8.1	7.66	1.6	14.2	1.6	0.7	2.366	2.069	0.580	0.083	5.219
PERCENT REMOVAL:		-10.	25.	10.	88.	66.	94.	96.	14.	2.	84.	-170.	-4240.
WINTER : DEC 26-MAR 20													
MEAN: INFLUENT		3.3	9.9	8.57	17.9	64.3	28.3	25.6	3.473	2.866	5.192	0.017	0.084
EFFLUENT		3.0	8.0	7.54	4.1	17.9	3.5	3.2	3.276	2.909	1.149	0.029	4.335
PERCENT REMOVAL:		10.	20.	12.	77.	72.	88.	87.	6.	-2.	78.	-71.	-5032.
SPRING : MAR 27-JUN 19													
MEAN: INFLUENT		12.4	4.7	8.37	43.2	98.4	40.7	29.6	3.358	2.465	2.675	0.053	0.240
EFFLUENT		12.9	6.1	7.38	2.4	15.9	1.2	0.8	2.523	2.413	0.418	0.065	3.686
PERCENT REMOVAL:		-5.	-31.	12.	95.	84.	97.	97.	25.	2.	84.	-24.	-1436.

TABLE A-2-2. SEASONAL SUMMARY FOR FILTER 2

FILTER 2 DATA

DATE	LOADING (MGAB)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
SUMMER : JUN 26-SEP 20													
MEAN: INFLUENT		21.3	6.8	8.85	8.1	70.5	30.7	24.8	2.066	1.604	1.649	0.031	0.149
EFFLUENT		22.0	6.3	7.99	2.0	25.7	7.9	2.3	1.577	1.434	0.354	0.137	3.542
PERCENT REMOVAL:		-3.	7.	10.	75.	64.	74.	91.	24.	11.	79.	-337.	-2280.
FALL : SEP 26-DEC 19													
MEAN: INFLUENT		9.4	9.5	8.38	11.6	37.1	27.4	15.6	2.824	2.110	3.758	0.028	0.107
EFFLUENT		10.9	7.1	7.67	1.5	14.3	3.2	1.0	2.477	2.042	0.874	0.166	4.603
PERCENT REMOVAL:		-16.	25.	9.	87.	61.	88.	94.	12.	3.	77.	-484.	-4198.
WINTER : DEC 26-MAR 20													
MEAN: INFLUENT		3.4	9.6	8.55	18.0	63.9	29.1	26.4	3.517	2.891	5.076	0.016	0.075
EFFLUENT		2.8	7.8	7.87	9.4	33.2	9.6	7.6	3.274	2.840	4.609	0.037	1.031
PERCENT REMOVAL:		18.	19.	8.	48.	48.	67.	71.	7.	2.	9.	-138.	-1284.
SPRING : MAR 27-JUN 19													
MEAN: INFLUENT		12.5	5.9	8.46	64.7	128.1	48.7	36.7	3.464	2.360	2.604	0.065	0.297
EFFLUENT		13.3	6.1	7.48	3.7	18.3	2.7	1.4	2.457	2.261	0.578	0.096	5.115
PERCENT REMOVAL:		-6.	-4.	12.	94.	86.	94.	96.	29.	4.	78.	-48.	-1621.

TABLE A-2-3. SEASONAL SUMMARY FOR FILTER 3

FILTER 3 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
SUMMER : JUN 26-SEP 20													
MEAN: INFLUENT		20.2	6.7	8.65	8.4	66.6	25.0	20.8	2.204	1.836	2.052	0.033	0.146
EFFLUENT		22.2	6.5	7.80	2.0	33.2	7.7	2.0	1.555	1.560	0.301	0.155	2.845
PERCENT REMOVAL:		-10.	3.	10.	76.	50.	69.	90.	29.	15.	85.	-364.	-1855.
FALL : SEP 26-DEC 19													
MEAN: INFLUENT		14.6	8.3	8.32	7.1	33.4	22.8	9.5	3.106	2.038	3.150	0.020	0.069
EFFLUENT		16.0	5.6	7.64	1.7	12.9	1.8	0.5	2.689	2.016	0.205	0.063	4.410
PERCENT REMOVAL:		-10.	32.	8.	77.	61.	92.	95.	13.	1.	93.	-212.	-6314.
WINTER : DEC 26-MAR 20													
MEAN: INFLUENT		3.8	13.2	8.74	15.8	47.3	26.3	19.0	2.643	2.262	4.521	0.031	0.165
EFFLUENT		0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000	0.000
PERCENT REMOVAL:		100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
SPRING : MAR 27-JUN 19													
MEAN: INFLUENT		2.9	9.3	8.44	17.6	60.9	25.6	23.5	3.605	3.015	5.232	0.014	0.064
EFFLUENT		0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.000	0.000	0.000	0.000	0.000
PERCENT REMOVAL:		100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.

TABLE A-2-4. SEASONAL SUMMARY FOR FILTER 4

FILTER 4 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
SUMMER : JUN 26-SEP 20													
MEAN: INFLUENT		20.4	6.6	8.67	7.8	68.2	20.8	17.4	2.286	1.901	2.203	0.038	0.169
EFFLUENT		23.0	6.0	8.03	2.8	33.2	9.2	2.5	1.695	1.634	0.463	0.193	2.632
PERCENT REMOVAL:		-13.	10.	7.	64.	51.	56.	85.	26.	14.	79.	-415.	-1454.
FALL : SEP 26-DEC 19													
MEAN: INFLUENT		12.4	8.8	8.42	11.4	43.5	29.3	18.4	3.076	2.323	3.180	0.027	0.077
EFFLUENT		13.2	7.1	7.66	1.2	16.5	2.1	0.7	2.642	2.065	0.270	0.188	4.177
PERCENT REMOVAL:		-6.	20.	9.	90.	62.	93.	96.	14.	-2.	92.	-602.	-5353.
WINTER : DEC 26-MAR 20													
MEAN: INFLUENT		3.3	9.9	8.57	17.9	64.3	28.3	25.6	3.473	2.866	5.192	0.017	0.084
EFFLUENT		2.7	8.6	7.66	4.0	19.2	5.1	3.9	3.475	3.148	1.777	0.126	5.065
PERCENT REMOVAL:		18.	13.	11.	77.	70.	82.	85.	-0.	-10.	66.	-653.	-5896.
SPRING : MAR 27-JUN 19													
MEAN: INFLUENT		7.2	8.2	8.43	16.7	64.1	35.5	24.6	3.144	2.536	3.339	0.051	0.231
EFFLUENT		7.5	8.1	7.54	2.4	18.6	3.8	2.9	2.791	2.593	0.604	0.033	1.823
PERCENT REMOVAL:		-4.	1.	11.	85.	71.	89.	88.	11.	-2.	82.	36.	-688.

TABLE A-2-5. SEASONAL SUMMARY FOR FILTER 5

FILTER 5 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
SUMMER : JUN 26-SEP 20													
MEAN: INFLUENT		20.7	8.0	8.84	7.7	68.1	21.8	18.6	2.016	1.636	1.686	0.034	0.163
EFFLUENT		21.7	6.2	7.95	2.9	33.4	7.1	1.5	1.637	1.639	0.433	0.222	2.846
PERCENT REMOVAL:		-5.	22.	10.	62.	51.	68.	92.	19.	-0.	74.	-550.	-1643.
FALL : SEP 26-DEC 19													
MEAN: INFLUENT		12.4	8.8	8.42	11.4	43.5	29.3	18.4	3.076	2.023	3.180	0.027	0.077
EFFLUENT		13.6	5.8	7.64	1.2	14.2	1.7	0.7	2.689	2.066	0.310	0.248	5.677
PERCENT REMOVAL:		-10.	34.	9.	89.	67.	94.	96.	13.	-2.	90.	-825.	-7311.
WINTER : DEC 26-MAR 20													
MEAN: INFLUENT		3.2	8.0	8.51	16.7	62.4	26.2	23.3	3.432	2.917	5.346	0.018	0.086
EFFLUENT		2.7	8.6	7.70	2.6	18.0	3.3	2.7	3.537	3.078	1.983	0.093	3.208
PERCENT REMOVAL:		15.	-7.	10.	84.	71.	87.	89.	-3.	-6.	63.	-410.	-3630.
SPRING : MAR 27-JUN 19													
MEAN: INFLUENT		13.5	8.5	8.66	8.6	43.9	20.0	14.2	2.617	2.108	2.243	0.062	0.323
: EFFLUENT		15.6	6.1	7.59	2.0	20.5	2.6	1.3	2.598	2.513	0.163	0.045	4.982
PERCENT REMOVAL:		-15.	26.	12.	77.	53.	87.	91.	1.	-19.	93.	28.	-1441.

TABLE A-2-6. SEASONAL SUMMARY FOR FILTER 6

FILTER 6 DATA

DATE	LOADING (MGAD)	TEMP (C)	D.O. (MG/L)	PH (MG/L)	BOD5 (MG/L)	COD (MG/L)	SS (MG/L)	VSS (MG/L)	TOTAL P (MG/L)	O-PO4-P (MG/L)	NH3-N (MG/L)	NO2-N (MG/L)	NO3-N (MG/L)
SUMMER : JUN 26-SEP 20													
MEAN: INFLUENT		20.4	7.0	8.72	8.1	67.4	29.1	22.4	2.129	1.697	1.820	0.030	0.138
EFFLUENT		20.9	7.0	7.72	1.6	28.3	6.6	1.0	1.844	1.817	0.106	0.082	5.010
PERCENT REMOVAL:		-5.	-1.	11.	80.	58.	77.	96.	13.	-7.	94.	-171.	-3532.
FALL : SEP 26-DEC 19													
MEAN: INFLUENT		8.1	10.6	8.51	13.5	41.4	27.6	17.8	2.775	2.111	3.757	0.031	0.120
EFFLUENT		8.7	8.8	7.68	1.1	12.0	1.8	0.5	2.434	2.198	0.367	0.084	4.967
PERCENT REMOVAL:		-8.	17.	10.	92.	71.	93.	97.	12.	-4.	90.	-167.	-4052.
WINTER : DEC 26-MAR 20													
MEAN: INFLUENT		2.8	9.7	8.48	17.5	61.6	25.0	22.8	3.546	2.974	5.355	0.016	0.076
EFFLUENT		2.2	8.3	7.72	3.7	16.7	3.4	2.8	3.333	2.888	2.347	0.022	2.527
PERCENT REMOVAL:		21.	14.	9.	79.	73.	87.	88.	6.	3.	56.	-37.	-3206.
SPRING : MAR 27-JUN 19													
MEAN: INFLUENT		11.8	6.1	8.45	38.7	92.7	39.6	29.0	3.249	2.410	2.522	0.053	0.251
EFFLUENT		11.9	7.5	7.45	1.1	10.2	2.1	0.7	2.708	2.644	0.118	0.009	6.104
PERCENT REMOVAL:		-1.	-23.	12.	97.	89.	95.	98.	17.	-10.	95.	83.	-2329.

TABLE A-3-1. EFFLUENT QUALITY WITH TIME FOR FILTER NUMBER 6 ON FEBRUARY 20, 1975, WITH A HYDRAULIC LOADING RATE OF 3741 m^3/ha.d (0.4 MGAD)

Loading Rate (gpad)	Time (min)	BOD mg/1	COD mg/1	SS mg/1	VSS mg/1	Total P mg/1	O-PO_4-P mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	pH	Temp. °C	DO mg/1
Influent	--	25.7	70.0	42.3	40.2	3.932	2.477	4.687	0.006	0.053	8.95	3.55	21.87
0.4	--	2.7	14.9	2.5	2.4	2.980	2.879	0.372	0.008	1.427	7.60	3.5	9.71
0.4	15	3.1	N.A.	3.8	3.4	3.000	3.000	0.340	0.010	1.213	7.62	2.8	9.14
0.4	30	3.9	13.1	4.1	3.7	3.152	3.015	0.289	0.009	1.339	7.70	3.0	9.75
0.4	45	4.5	N.A.	4.5	4.1	3.000	2.939	0.319	0.011	1.337	7.66	2.9	9.23
0.4	60	4.0	17.2	4.6	4.5	3.015	2.803	0.239	0.010	1.177	7.72	2.8	9.27
0.4	90	3.6	N.A.	4.2	3.9	3.046	2.955	0.247	0.010	1.740	7.69	2.8	9.33
0.4	120	3.5	14.0	3.8	3.3	2.955	2.879	0.376	0.010	1.088	7.62	2.7	9.32
0.4	240	1.3	12.6	2.9	2.7	2.909	2.864	0.456	0.010	2.956	7.63	2.8	9.45
0.4	360	2.9	16.6	1.9	1.8	3.106	3.106	0.389	0.011	2.908	7.70	2.8	9.53
0.4	480	3.5	14.4	2.4	2.2	3.061	3.060	0.335	0.011	2.765	7.45	3.5	9.55
0.4	600	2.7	21.0	2.6	2.6	2.894	2.909	0.270	0.015	2.681	7.76	2.5	9.47
0.4	840	3.4	14.2	2.9	2.9	2.970	2.864	0.270	0.009	2.285	7.74	2.5	9.54
0.4	1440	1.9	14.7	2.5	2.3	3.000	2.989	0.181	0.005	2.147	7.52	--	9.29

Appendix B

Weekly Effluent Comparisons Between Filters for Each Parameter and Their Removal Efficiencies

TABLE B-1. FILTER EFFLUENT COMPARISONS FOR TEMPERATURE

DATA COMPARISON FOR TEMP (CENT.)

DATE	INF	1	2	3	4	5	6
JUL 2	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
12	21.0	24.0	21.0	22.5	21.5	21.5	22.0
15	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
17	24.5	25.5	25.5	27.0	27.0	25.0	24.0
18	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
19	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
22	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
24	24.5	25.3	25.1	25.7	25.7	25.5	25.1
26	-5.0	-5.0	-5.0	-5.0	-5.0	-1.0	-5.0
31	-5.0	24.2	24.6	24.7	-1.0	-1.0	-5.0
AUG 6	-5.0	-5.0	-5.0	-1.0	-1.0	-1.0	-5.0
7	22.9	23.0	22.3	-1.0	-1.0	-1.0	23.2
14	19.9	-1.0	20.1	20.9	20.7	20.1	-5.0
16	-5.0	-1.0	-5.0	-5.0	-1.0	-1.0	-5.0
19	-5.0	-1.0	-5.0	-5.0	-1.0	-1.0	-5.0
21	19.0	-1.0	19.0	-1.0	-1.0	-1.0	21.0
SEP 4	19.2	20.2	20.1	20.1	20.0	21.5	20.5
6	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
9	-5.0	-5.0	-5.0	-5.0	-1.0	-5.0	-5.0
11	19.0	19.1	20.2	20.0	-1.0	-5.0	18.5
18	17.1	19.4	-1.0	16.9	-5.0	16.7	16.9
20	-5.0	-5.0	-1.0	-5.0	-5.0	-5.0	-5.0
26	16.8	18.1	16.8	18.0	15.8	17.1	15.9
OCT 3	15.1	14.8	16.8	16.0	16.1	16.5	14.7
10	-5.0	14.4	14.8	15.2	14.8	14.6	13.9
17	11.9	13.0	13.5	14.9	-1.0	-1.0	12.5
24	11.9	12.2	-1.0	-1.0	12.0	12.0	11.9
31	9.5	10.3	-5.0	-1.0	-1.0	-1.0	10.1
NOV 7	7.1	-1.0	8.3	-1.0	-1.0	-1.0	8.4
14	5.8	6.5	6.8		7.3	7.8	6.7
21	5.1	5.5	6.3		-1.0	-1.0	5.4
26	4.1	4.1	4.0		-1.0	-1.0	4.6
DEC 5	3.7	4.0	-1.0		-1.0	-1.0	4.2
12	2.7	3.3	-1.0		-1.0	-1.0	3.1
19	3.4	2.2	-1.0		-1.0	-1.0	2.3
26	2.1	3.0	-1.0		1.8	2.0	2.0
JAN 2	2.8	1.5	1.2		1.1	1.0	2.8
9	3.0	1.0	1.0		1.2	1.2	1.5
16	3.0	1.8	1.2		1.0	1.0	1.2
23	2.0	1.5	1.5		2.0	1.9	1.8
30	2.0	1.5	1.5		1.0	1.5	1.5
FEB 6	2.0	2.0	0.5		2.0	1.8	1.0
13	2.5	2.7	-5.0		3.0	3.2	3.0
20	3.6	2.7	2.9		2.7	-1.0	2.0
27	3.5	3.2	3.7		2.1	-1.0	2.4
MAR 6	4.5	5.1	5.5		5.0	4.1	5.3
13	4.9	5.9	5.3		5.9	5.9	-1.0
20	6.7	6.5	6.0		6.0	6.5	-1.0
27	2.5	-1.0	-1.0		4.0	-1.0	-1.0
APR 3	4.7	-1.0	-1.0		5.2	-1.0	5.0
10	6.1	6.5	-1.0		6.6	-1.0	6.2
17	6.7	7.9	7.2		6.0	-1.0	7.0
24	10.1	11.2	11.1		11.0	-1.0	11.2

(Continued)

TABLE B-1. (CONTINUED)

DATE	INF	1	2	3	4	5	6
MAY 1	10.5	10.5	-1.0		11.0	10.4	10.3
8	10.0	9.0	-1.0		9.0	-1.0	9.0
15	13.5	-1.0	15.4		-1.0	17.8	15.6
22	12.1	13.2	13.0		-1.0	13.5	12.0
29	15.1	15.7	16.0		-1.0	-1.0	15.6
JUN 5	17.7	18.4	17.0			-1.0	16.6
12	18.0	20.0	-1.0			20.7	17.8
19	17.2	17.0	-1.0			-1.0	16.8
26	16.5	17.0	-1.0			-1.0	17.0

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-2. FILTER EFFLUENT COMPARISONS FOR DISSOLVED OXYGEN

DATA COMPARISON FOR D.O. (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
12	2.2	7.0	7.0	7.1	6.8	6.4	6.4
15	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
17	1.6	5.9	5.7	5.1	4.0	4.7	6.2
18	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
19	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
22	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
24	3.4	6.3	5.7	5.8	4.1	3.3	6.1
26	-5.0	-5.0	-5.0	-5.0	-5.0	-1.0	-5.0
31	3.4	5.6	4.8	4.7	-1.0	-1.0	-5.0
AUG 6	-5.0	-5.0	-5.0	-1.0	-1.0	-1.0	-5.0
7	10.5	5.9	6.1	-1.0	-1.0	-1.0	6.1
14	10.9	-1.0	7.9	8.0	7.9	8.2	-5.0
16	-5.0	-1.0	-5.0	-5.0	-1.0	-1.0	-5.0
19	-5.0	-1.0	-5.0	-5.0	-1.0	-1.0	-5.0
21	5.9	-1.0	6.3	-1.0	-1.0	-1.0	6.8
SEP 4	12.5	7.5	7.2	7.3	7.1	7.2	7.3
6	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
9	-5.0	-5.0	-5.0	-5.0	-1.0	-5.0	-5.0
11	10.6	7.2	6.3	6.0	-1.0	-5.0	7.4
18	14.7	7.2	-1.0	7.8	-5.0	7.7	8.2
20	-5.0	-5.0	-1.0	-5.0	-5.0	-5.0	-5.0
26	7.1	7.4	8.0	6.2	5.7	5.8	8.5
OCT 3	7.2	7.4	5.8	4.7	6.4	5.8	7.4
10	-5.0	7.7	6.8	6.0	6.7	3.3	8.1
17	10.6	7.4	4.9	5.6	-1.0	-1.0	7.4
24	8.1	7.5	-1.0	-1.0	7.5	5.4	7.8
31	8.0	7.7	-5.0	-1.0	-1.0	-1.0	7.7

(Continued)

TABLE B-2. (CONTINUED)

DATE	INF	1	2	3	4	5	6
NOV 7	8.2	-1.0	7.7	-1.0	-1.0	-1.0	10.1
14	12.9	8.4	8.0		9.0	8.7	11.1
21	9.8	7.9	7.6		-1.0	-1.0	8.0
28	11.8	10.0	7.8		-1.0	-1.0	11.5
DEC 5	16.0	9.9	-1.0		-1.0	-1.0	9.5
12	12.0	6.8	-1.0		-1.0	-1.0	7.5
19	15.6	8.9	-1.0		-1.0	-1.0	9.6
26	14.0	14.4	-1.0		13.2	12.4	15.4
JAN 2	4.6	4.0	10.6		8.8	9.8	6.7
9	3.8	7.2	7.2		8.1	7.9	3.8
16	3.2	7.3	7.2		6.6	5.3	6.5
23	0.2	7.1	7.7		8.8	7.7	9.4
30	4.0	7.6	7.0		7.3	9.8	8.4
FEB 6	5.4	8.7	7.1		9.4	8.2	8.7
13	12.9	8.7	5.6		8.0	8.4	8.5
20	21.9	9.3	10.8		9.3	-1.0	8.4
27	18.9	6.5	8.0		7.1	-1.0	7.9
MAR 6	18.1	7.7	8.2		8.8	9.5	8.0
13	9.5	7.8	6.4		7.6	6.8	-1.0
20	12.6	7.4	7.4		8.7	8.5	-1.0
27	10.0	-1.0	-1.0		8.6	-1.0	-1.0
APR 3	12.3	-1.0	-1.0		7.3	-1.0	9.2
10	3.6	7.3	-1.0		8.5	-1.0	8.2
17	4.3	7.0	5.8		8.3	-1.0	7.3
24	6.7	6.6	6.8		7.9	-1.0	7.3
MAY 1	12.0	6.2	-1.0		7.9	7.4	7.6
8	-5.0	-5.0	-1.0		-5.0	-1.0	-5.0
15	12.8	-1.0	7.9		-1.0	5.2	8.6
22	6.2	6.6	6.3		-1.0	6.5	7.1
29	4.5	6.1	6.0		-1.0	-1.0	7.0
JUN 5	0.7	4.6	3.8			-1.0	6.6
12	2.8	5.0	-1.0			5.3	6.8
19	1.1	5.6	-1.0			-1.0	6.7
26	1.0	6.9	-1.0			-1.0	8.6

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-3. FILTER EFFLUENT COMPARISONS FOR pH

DATA COMPARISON FOR PH

DATE	INF	1	2	3	4	5	6
JUL 2	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
12	8.80	8.10	8.10	7.90	8.10	8.00	7.80
15	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
17	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
18	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
19	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
22	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
24	8.85	8.13	8.12	7.88	8.02	8.23	8.10
26	-5.00	-5.00	-5.00	-5.00	-5.00	-1.00	-5.00
31	8.46	7.74	7.68	7.78	-1.00	-1.00	-5.00
AUG 6	-5.00	-5.00	-5.00	-1.00	-1.00	-1.00	-5.00
7	8.90	8.10	8.20	-1.00	-1.00	-1.00	8.00
14	9.20	-1.00	8.18	8.15	8.11	8.11	-5.00
16	-5.00	-1.00	-5.00	-5.00	-1.00	-1.00	-5.00
19	-5.00	-1.00	-5.00	-5.00	-1.00	-1.00	-5.00
21	9.10	-1.00	8.21	-1.00	-1.00	-1.00	7.93
SEP 4	8.80	7.70	7.80	7.70	7.90	8.00	7.60
6	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
9	-5.00	-5.00	-5.00	-5.00	-1.00	-5.00	-5.00
11	8.70	7.70	7.60	7.80	-1.00	-5.00	7.60
18	8.70	7.40	-1.00	7.40	-5.00	7.40	7.50
20	-5.00	-5.00	-1.00	-5.00	-5.00	-5.00	-5.00
26	8.37	7.80	7.78	7.89	7.66	7.90	7.80
OCT 3	8.18	7.67	7.49	7.58	7.54	7.55	7.65
10	-5.00	7.74	7.70	7.50	7.70	7.59	7.76
17	8.40	7.50	7.60	7.60	-1.00	-1.00	7.60
24	8.40	7.70	-1.00	-1.00	7.70	7.58	7.63
31	8.19	7.78	-5.00	-1.00	-1.00	-1.00	7.61
NOV 7	8.17	-1.00	7.91	-1.00	-1.00	-1.00	7.46
14	8.72	7.50	7.36		7.69	7.58	7.50
21	8.72	7.89	7.80		-1.00	-1.00	7.85
26	8.29	7.62	7.70		-1.00	-1.00	7.60
DEC 5	8.95	7.58	-1.00		-1.00	-1.00	7.77
12	8.81	7.55	-1.00		-1.00	-1.00	7.81
19	8.87	7.60	-1.00		-1.00	-1.00	7.82
26	8.82	7.55	-1.00		8.05	8.03	7.70
JAN 2	8.49	7.44	7.63		7.58	8.49	7.53
9	8.46	7.50	7.92		7.82	7.78	8.02
16	8.00	7.37	7.71		7.41	7.36	7.61
23	8.20	7.42	7.98		7.50	7.52	7.25
30	8.15	7.20	7.88		7.61	7.65	7.61
FEB 6	8.00	7.45	7.64		7.68	7.39	7.79
13	8.30	7.45	7.96		7.52	7.62	7.69
20	8.95	7.62	7.90		7.60	-1.00	7.68
27	8.88	7.57	7.92		7.52	-1.00	7.64
MAR 6	9.01	7.88	8.07		7.85	7.71	7.55
13	8.70	7.60	7.79		7.61	7.51	-1.00
20	9.50	7.95	7.98		7.79	7.65	-1.00
27	8.62	-1.00	-1.00		7.72	-1.00	-1.00
APR 3	8.80	-1.00	-1.00		7.61	-1.00	7.58
10	8.27	7.37	-1.00		7.15	-1.00	7.28
17	7.94	7.14	7.18		7.41	-1.00	7.37
24	8.10	7.60	7.60		7.60	-1.00	7.40
MAY 1	8.56	7.32	-1.00		7.47	7.43	7.42
8	8.70	7.60	-1.00		7.80	-1.00	7.50
15	8.90	-1.00	7.30		-1.00	7.40	7.40

(Continued)

TABLE B-3. (CONTINUED)

DATE	INF	1	2	3	4	5	6
22	8.90	7.30	7.80		-1.00	7.90	7.60
29	8.50	7.30	7.50		-1.00	-1.00	7.40
JUN 5	8.40	7.25	7.52			-1.00	7.35
12	8.28	7.40	-1.00			7.62	7.55
19	8.00	7.50	-1.00			-1.00	7.60
26	7.68	7.10	-1.00			-1.00	7.25

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-4. FILTER EFFLUENT COMPARISONS AND REMOVAL EFFICIENCIES FOR BIOCHEMICAL OXYGEN DEMAND

DATA COMPARISON FOR BOD5 (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	3.5	2.4	2.2	2.6	3.4	2.7	2.1
12	8.1	2.6	3.7	4.0	4.6	4.5	2.2
15	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
17	8.1	1.0	1.4	1.7	2.0	6.0	6.0
18	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
19	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
22	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
24	4.0	1.9	2.0	2.1	1.8	2.4	0.9
26	-5.0	-5.0	-5.0	-5.0	-5.0	-1.0	-5.0
31	14.3	1.3	1.5	2.8	-1.0	-1.0	-5.0
AUG 6	-5.0	-5.0	-5.0	-1.0	-1.0	-1.0	-5.0
7	6.0	1.7	2.7	-1.0	0.0	-1.0	1.7
14	12.9	-1.0	3.2	3.0	3.4	2.7	-5.0
16	-5.0	-1.0	-5.0	-5.0	-1.0	-1.0	-5.0
19	-5.0	-1.0	-5.0	-5.0	-1.0	-1.0	-5.0
21	6.3	-1.0	1.0	-1.0	-1.0	-1.0	0.5
SEP 4	8.8	2.4	1.5	1.5	1.7	-5.0	1.0
6	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
9	10.4	2.2	2.1	0.8	-1.0	2.5	0.9
11	6.4	2.0	0.8	0.9	-1.0	2.9	1.4
18	6.4	0.8	-1.0	2.2	2.9	2.1	1.2
20	8.0	0.4	-1.0	0.8	-5.0	0.7	0.9
26	3.9	1.2	2.0	0.8	1.4	0.8	0.8

(Continued)

TABLE B-4. (CONTINUED)

DATE	INF	1	2	3	4	5	6
OCT 3	6.4	1.8	1.4	0.8	1.0	1.0	2.2
10	7.7	1.3	0.7	1.7	1.2	1.7	1.0
17	10.4	1.2	2.0	3.3	-1.0	-1.0	1.0
24	19.3	1.7	-1.0	-1.0	1.2	1.3	0.8
31	22.0	2.1	-5.0	-1.0	-1.0	-1.0	1.4
NOV 7	12.0	-1.0	0.8	-1.0	-1.0	-1.0	0.8
14	19.9	1.3	1.4		1.2	1.3	0.6
21	8.7	1.7	1.6		-1.0	-1.0	1.4
28	13.3	1.4	1.8		-1.0	-1.0	0.6
DEC 5	19.2	1.4	-1.0		-1.0	-1.0	0.8
12	22.7	2.0	-1.0		-1.0	-1.0	1.9
19	10.0	1.8	-1.0		-1.0	-1.0	1.4
26	16.7	1.4	-1.0		2.5	1.6	1.4
JAN 2	8.5	1.4	6.0		2.2	1.6	1.3
9	5.3	1.7	2.1		2.3	1.9	1.6
16	12.1	2.4	5.7		2.6	2.1	2.9
23	12.5	3.3	10.4		3.3	1.9	4.5
30	19.7	7.5	9.4		7.1	4.2	3.9
FEB 6	28.1	5.2	9.0		11.6	3.6	3.9
13	22.4	4.4	13.5		3.1	5.3	3.7
20	25.7	3.5	13.0		2.2	-1.0	8.5
27	23.4	4.7	9.5		3.1	-1.0	3.6
MAR 6	18.1	5.7	15.3		2.9	1.9	5.5
13	17.0	4.8	9.2		4.1	1.6	-1.0
20	23.1	6.8	9.9		5.2	2.5	-1.0
27	20.2	-1.0	-1.0		2.7	-1.0	-1.0
APR 3	21.6	-1.0	-1.0		2.5	-1.0	2.8
10	15.2	4.8	-1.0		2.4	-1.0	1.4
17	10.9	3.2	5.0		2.7	-1.0	1.2
24	25.1	3.8	5.7		2.8	-1.0	1.2
MAY 1	10.2	2.8	-1.0		1.8	2.4	1.0
8	13.4	1.9	-1.0		2.1	-1.0	0.6
15	10.3	-1.0	2.3		-1.0	1.6	0.7
22	5.4	1.0	1.4		-1.0	2.2	0.9
29	48.4	1.0	1.8		-1.0	-1.0	0.7
JUN 5	288.0	1.2	6.2			-1.0	0.8
12	8.5	1.7	-1.0			1.4	0.7
19	7.1	2.3	-1.0			-1.0	1.0
26	10.0	2.2	-1.0			-1.0	0.7

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-5. FILTER EFFLUENT COMPARISONS AND REMOVAL EFFICIENCIES FOR CHEMICAL OXYGEN DEMAND

DATA COMPARISON FOR COD (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	37.0	25.0	27.0	39.0	23.0	19.0	30.0
12	64.5	20.4	26.1	56.8	31.9	26.1	26.1
15	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
17	75.0	69.0	16.0	5.0	61.0	87.0	44.0
18	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
19	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
22	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
24	89.8	21.9	53.0	77.4	26.6	31.6	88.3
26	-5.0	-5.0	-5.0	-5.0	-5.0	-1.0	-5.0
31	54.8	16.1	19.0	23.2	-1.0	-1.0	-5.0
AUG 6	-5.0	-5.0	-5.0	-1.0	-1.0	-1.0	-5.0
7	64.4	11.4	23.6	-1.0	-1.0	-1.0	9.8
14	84.8	-1.0	30.4	27.8	35.1	30.6	-5.0
16	-5.0	-1.0	-5.0	-5.0	-1.0	-1.0	-5.0
19	-5.0	-1.0	-5.0	-5.0	-1.0	-1.0	-5.0
21	78.3	-1.0	14.6	-1.0	-1.0	-1.0	8.3
SEP 4	91.3	27.5	30.2	29.3	29.2	26.5	28.1
6	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
9	-5.0	-5.0	-5.0	-5.0	-1.0	-5.0	-5.0
11	65.5	22.4	16.8	14.4	-1.0	20.0	18.8
18	37.0	15.6	-1.0	25.8	25.6	26.4	19.2
20	-5.0	-5.0	-1.0	-5.0	-5.0	-5.0	-5.0
26	27.9	16.3	21.0	11.2	19.7	16.9	18.9
OCT 3	33.8	16.9	15.2	16.7	15.6	12.3	12.3
10	36.4	13.2	14.1	14.3	17.1	16.5	12.7
17	35.4	10.6	10.4	9.5	-1.0	-1.0	10.3
24	66.2	11.8	-1.0	-1.0	15.2	10.7	10.0
31	42.7	13.7	-5.0	-1.0	-1.0	-1.0	7.0
NOV 7	33.4	-1.0	11.9	-1.0	-1.0	-1.0	14.9
14	53.0	25.1	14.6		14.9	12.6	11.1
21	34.1	14.5	13.8		-1.0	-1.0	7.5
26	36.9	10.7	13.2		-1.0	-1.0	9.4
DEC 5	45.8	11.8	-1.0		-1.0	-1.0	12.5
12	57.7	12.0	-1.0		-1.0	-1.0	16.1
19	34.9	13.4	-1.0		-1.0	-1.0	13.4
26	68.8	13.5	-1.0		18.4	17.1	12.6
JAN 2	34.0	12.9	23.1		11.0	16.3	11.9
9	31.2	12.8	16.6		13.4	14.3	11.5
16	43.7	12.9	24.6		17.0	14.8	16.1
23	46.2	15.0	30.0		15.5	15.1	18.3
30	61.8	12.8	35.7		26.5	24.5	15.1
FEB 6	71.9	22.6	38.4		31.2	20.3	23.2
13	80.7	19.5	50.6		19.9	24.1	16.2
20	70.0	14.0	32.2		15.2	-1.0	20.7
27	78.9	22.5	39.9		22.9	-1.0	19.6
MAR 6	90.8	24.9	44.7		14.6	19.9	18.7
13	74.3	26.6	28.1		23.7	16.0	-1.0
20	83.0	23.3	34.3		19.6	15.1	-1.0
27	82.9	-1.0	-1.0		21.7	-1.0	-1.0
APR 3	83.4	-1.0	-1.0		17.2	-1.0	17.3
10	61.6	21.7	-1.0		18.2	-1.0	9.7
17	54.9	20.5	17.3		21.9	-1.0	8.8
24	50.3	20.3	16.3		18.5	-1.0	7.1
MAY 1	55.2	19.5	-1.0		15.2	24.5	7.0
8	60.6	11.6	-1.0		17.3	-1.0	7.0
15	45.9	-1.0	16.9		-1.0	15.0	9.3

(Continued)

TABLE B-5. (CONTINUED)

DATE	INF	1	2	3	4	5	6
22	36.0	11.6	11.6		-1.0	19.4	9.1
29	140.8	15.5	18.2		-1.0	-1.0	16.8
JUN 5	440.9	15.4	29.2		-1.0	-1.0	10.4
12	38.6	12.5	-1.0		-1.0	23.0	14.2
19	44.7	10.7	-1.0		-1.0	-1.0	6.2
26	66.2	12.1	-1.0		-1.0	-1.0	10.3
					-1.0	-1.0	10.3

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

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TABLE B-6. FILTER EFFLUENT COMPARISONS AND REMOVAL EFFICIENCIES FOR SUSPENDED SOLIDS

DATA COMPARISON FOR SS (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	10.9	2.7	3.2	2.3	3.0	2.2	2.4
12	24.9	30.9	29.6	11.9	11.1	6.9	34.6
15	8.2	1.7	4.2	2.9	7.9	17.9	3.2
17	10.0	7.6	22.4	17.8	18.5	17.6	8.2
18	7.4	9.1	8.9	12.3	6.1	5.9	19.6
19	5.6	11.4	19.3	28.1	15.6	10.0	17.4
22	5.9	1.9	3.3	3.8	6.2	3.7	2.7
24	10.9	2.5	3.1	3.8	4.1	1.1	2.2
26	23.4	1.8	2.6	2.1	3.3	-1.0	2.2
31	16.8	1.7	2.2	2.3	-1.0	-1.0	-5.0
AUG 6	72.1	2.0	3.9	-1.0	-1.0	-1.0	-5.0
7	39.3	2.9	7.2	-1.0	-1.0	-1.0	5.1
14	55.7	-1.0	9.0	16.3	15.2	12.4	-5.0
16	55.2	-1.0	7.3	7.0	-1.0	-1.0	-5.0
19	51.9	-1.0	3.4	5.3	-1.0	-1.0	1.6
21	56.9	-1.0	4.0	-1.0	-1.0	-1.0	2.4
SEP 4	30.4	9.4	15.4	11.7	14.6	9.9	6.6
6	43.9	4.9	3.8	5.2	4.4	2.9	2.1
9	34.0	2.3	3.3	3.3	-1.0	4.3	2.5
11	30.8	3.3	2.3	2.6	-1.0	2.1	1.7
18	14.0	1.3	-1.0	5.7	9.5	6.1	2.3
20	13.8	1.2	-1.0	2.1	-5.0	3.0	2.0
26	22.7	0.6	9.3	1.4	1.2	1.2	1.5
OCT 3	16.5	1.7	1.7	2.0	2.3	1.7	1.5
10	23.1	1.2	2.0	1.5	2.0	1.8	2.7
17	28.9	2.7	2.7	2.2	-1.0	-1.0	2.3
24	43.5	1.3	-1.0	-1.0	2.4	1.8	1.6
31	33.3	0.7	-5.0	-1.0	-1.0	-1.0	2.3
NOV 7	26.1	-1.0	3.1	-1.0	-1.0	-1.0	1.6
14	40.8	1.5	1.9		2.4	2.0	2.0
21	22.7	1.3	2.5		-1.0	-1.0	1.4
28	32.8	1.8	2.7		-1.0	-1.0	1.9
DEC 5	23.4	1.6	-1.0		-1.0	-1.0	1.7
12	30.7	2.2	-1.0		-1.0	-1.0	1.6
19	14.9	2.0	-1.0		-1.0	-1.0	1.7
26	19.1	1.2	-1.0		2.6	1.6	1.4
JAN 2	8.6	0.9	4.8		2.4	1.3	1.1
9	5.5	1.2	4.2		1.9	2.0	1.3
16	11.3	1.5	5.2		2.6	1.5	0.9
23	13.4	2.1	5.2		2.6	2.2	2.5
30	24.9	2.8	10.8		8.0	3.9	3.2

(Continued)

TABLE B-6. (CONTINUED)

DATE	INF	1	2	3	4	5	6
FEB 6	28.7	4.1	8.7		9.9	4.3	3.6
13	39.4	5.4	18.3		5.6	6.1	4.5
20	42.3	3.8	12.0		4.9	-1.0	7.3
27	37.9	6.6	11.5		6.1	-1.0	6.9
MAR 6	43.8	6.5	10.8		3.7	6.3	4.3
13	38.6	5.0	9.2		6.3	3.8	-1.0
20	54.7	4.9	14.6		9.2	3.8	-1.0
27	51.1	-1.0	-1.0		7.8	-1.0	-1.0
APR 3	48.0	-1.0	-1.0		4.4	-1.0	2.7
10	26.5	2.5	-1.0		3.2	-1.0	1.7
17	21.5	1.0	3.5		3.1	-1.0	1.4
24	25.2	0.7	2.8		2.8	-1.0	1.2
MAY 1	32.4	0.8	-1.0		2.1	3.0	0.8
8	43.6	0.7	-1.0		3.1	-1.0	1.2
15	19.9	-1.0	3.3		-1.0	2.7	2.1
22	7.9	1.3	1.9		-1.0	1.6	2.2
29	67.5	1.1	2.1		-1.0	-1.0	2.1
JUN 5	130.2	1.0	2.6		-1.0	-1.0	2.8
12	19.9	1.4	-1.0		-1.0	3.1	3.6
19	12.2	1.1	-1.0		-1.0	-1.0	3.0
26	26.9	2.5	-1.0		-1.0	-1.0	6.8

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-7. FILTER EFFLUENT COMPARISONS AND REMOVAL EFFICIENCIES FOR VOLATILE SUSPENDED SOLIDS

DATA COMPARISON FOR VSS (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	2.6	0.0	0.8	0.5	1.1	0.7	0.4
12	17.1	2.5	3.6	1.3	1.3	1.7	2.0
15	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
17	4.2	0.0	0.7	0.8	1.1	0.4	0.0
18	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
19	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
22	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0
24	6.4	1.1	0.5	0.6	0.6	0.0	0.0
26	-5.0	-5.0	-5.0	-5.0	-5.0	-1.0	-5.0
31	11.5	0.9	0.5	1.1	-1.0	-1.0	-5.0
AUG 6	-5.0	-5.0	-5.0	-1.0	-1.0	-1.0	-5.0
7	31.5	2.3	4.8	-1.0	-1.0	-1.0	2.9
14	44.3	-1.0	5.4	5.6	5.3	5.4	-5.0
16	39.2	-1.0	3.9	5.1	-1.0	-1.0	-5.0
19	40.8	-1.0	2.3	2.9	-1.0	-1.0	0.9
21	36.6	-1.0	2.6	-1.0	-1.0	-1.0	1.2
SEP 4	39.1	3.0	3.2	3.6	6.5	2.7	2.2
6	27.2	1.4	0.8	3.1	1.6	1.2	0.4
9	26.2	0.0	1.0	1.3	-1.0	1.5	1.5
11	20.8	1.6	1.4	1.2	-1.0	1.5	0.6

(Continued)

TABLE B-7. (CONTINUED)

DATE	INF	1	2	3	4	5	6
12	8.6	0.6	-1.0	1.3	2.8	0.9	0.6
20	7.8	0.2	-1.0		-5.0	0.7	0.2
26	11.5	0.2	1.3	0.3	0.1	0.5	0.4
OCT 3	6.0	0.1	0.3	0.5	0.5	0.6	0.4
10	11.4	0.6	0.5	0.7	0.9	0.7	0.6
17	8.9	0.7	0.6	0.4	-1.0	-1.0	0.3
24	33.5	0.2	-1.0	-1.0	1.1	1.2	0.5
31	25.3	0.6	-5.0	-1.0	-1.0	-1.0	0.4
NOV 7	18.2	-1.0	1.4	-1.0	-1.0	-1.0	0.5
14	29.5	1.0	1.1		0.7	0.6	0.6
21	11.5	0.6	1.2		-1.0	-1.0	0.2
28	19.2	0.8	1.2		-1.0	-1.0	0.4
DEC 5	18.1	1.0	-1.0		-1.0	-1.0	0.6
12	26.9	1.6	-1.0		-1.0	-1.0	1.0
19	11.9	1.5	-1.0		-1.0	-1.0	1.0
26	16.6	0.9	-1.0		0.9	0.9	0.8
JAN 2	6.8	0.8	3.5		1.1	0.7	0.9
9	4.0	1.1	1.2		1.0	1.2	1.0
16	6.0	0.3	0.7			0.5	0.5
23	11.6	2.0	3.5		1.7	1.5	2.1
30	22.3	2.5	8.1		7.2	3.3	3.0
FEB 6	27.2	3.8	7.1		9.0	3.8	3.1
13	39.4	5.4	14.8		4.8	5.6	3.9
20	40.2	3.3	10.8		4.1	-1.0	6.0
27	36.7	6.0	10.5		4.6	-1.0	5.4
MAR 6	40.4	6.1	9.8		3.3	5.5	3.9
13	36.0	4.9	8.3		5.8	3.4	-1.0
20	45.9	4.7	13.2		7.3	2.9	-1.0
27	42.1	-1.0	-1.0		6.7	-1.0	-1.0
APR 3	38.4	-1.0	-1.0		3.5	-1.0	1.6
10	18.6	2.5	-1.0		2.5	-1.0	1.2
17	11.1	0.8	1.9		2.0	-1.0	0.6
24	12.2	0.5	1.7		1.7	-1.0	0.5
MAY 1	22.3	0.8	-1.0		1.8	1.9	0.5
8	27.6	0.6	-1.0		2.3	-1.0	0.5
15	14.2	-1.0	1.9		-1.0	1.8	0.7
22	4.6	0.6	0.5		-1.0	0.7	0.5
29	69.0	0.6	1.0		-1.0	-1.0	1.1
JUN 5	109.1	0.5	1.6		-1.0	-1.0	0.5
12	15.6	0.7	-1.0		-1.0	0.8	0.6
19	5.6	0.5	-1.0		-1.0	-1.0	0.4
26	16.9	0.6	-1.0		-1.0	-1.0	0.5

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-8. FILTER EFFLUENT COMPARISONS AND REMOVAL EFFICIENCIES FOR TOTAL SOLUBLE PHOSPHORUS

DATA COMPARISON FOR TOTAL P (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	3.330	1.631	3.057	2.750	2.769	3.173	3.000
12	2.112	1.508	1.986	2.049	2.011	1.911	2.059
15	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
17	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
18	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
19	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
22	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
24	2.204	1.676	1.765	1.794	1.941	1.641	1.641
26	-5.000	-5.000	-5.000	-5.000	-5.000	-1.000	-5.000
31	2.313	1.870	2.090	1.747	-1.000	-1.000	-5.000
AUG 6	-5.000	-5.000	-5.000	-1.000	-1.000	-1.000	-5.000
7	1.699	1.324	1.255	-1.000	-1.000	-1.000	1.528
14	1.807	-1.000	1.333	1.481	1.422	1.410	-5.000
16	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
19	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
21	1.893	-1.000	0.946	-1.000	-1.000	-1.000	1.222
SEP 4	1.721	1.279	0.921	0.939	1.061	1.054	1.315
6	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
9	-5.000	-5.000	-5.000	-5.000	-1.000	-5.000	-5.000
11	1.517	0.864	0.841	0.811	-1.000	1.164	1.087
18	1.424	0.781	-1.000	0.866	0.964	1.103	0.951
20	-5.000	-5.000	-1.000	-5.000	-5.000	-5.000	-5.000
26	2.154	1.193	1.151	1.323	1.411	1.505	1.505
OCT 3	2.488	1.866	1.925	2.103	2.296	2.280	1.841
10	5.387	5.124	4.897	5.076	5.028	5.148	4.659
17	2.397	2.373	2.289	2.253	-1.000	-1.000	2.301
24	2.714	2.024	-1.000	-1.000	2.431	2.510	1.685
31	2.377	1.383	-5.000	-1.000	-1.000	-1.000	2.069
NOV 7	3.015	-1.000	2.313	-1.000	-1.000	-1.000	2.302
14	2.637	1.970	2.311		2.044	2.000	2.296
21	2.193	2.222	2.208		-1.000	-1.000	2.308
26	2.767	2.767	2.719		-1.000	-1.000	3.330
DEC 5	2.672	2.641	-1.000		-1.000	-1.000	2.596
12	2.870	2.519	-1.000		-1.000	-1.000	2.427
19	2.409	2.307	-1.000		-1.000	-1.000	2.321
26	2.950	2.718	-1.000		2.658	2.950	2.610
JAN 2	2.896	2.697	2.851		3.218	3.157	2.805
9	3.137	2.950	2.906		2.748	2.715	2.734
16	3.375	3.025	3.287		2.996	3.084	3.098
23	3.802	3.498	3.513		3.513	3.634	3.574
30	3.852	3.570	3.541		3.719	3.360	3.393
FEB 6	4.091	3.574	3.513		3.529	3.924	3.437
13	3.896	3.435	3.420		3.480	3.554	3.138
20	3.932	2.955	2.758		3.015	-1.000	2.848
27	3.466	3.023	3.008		3.573	-1.000	3.420
MAR 6	3.606	5.727	5.136		6.667	6.439	5.605
13	2.951	2.861	2.756		3.161	3.206	-1.000
20	3.200	2.554	2.600		2.892	2.877	-1.000
27	3.292	-1.000	-1.000		2.974	-1.000	-1.000
APR 3	3.024	-1.000	-1.000		2.748	-1.000	2.211
10	3.215	2.508	-1.000		2.954	-1.000	2.615
17	3.234	2.656	1.906		2.796	-1.000	2.922
24	3.234	2.671	2.640		2.688	-1.000	3.031
MAY 1	3.032	2.770	-1.000		2.770	3.331	3.082
8	2.975	2.320	-1.000		2.608	-1.000	2.704
15	2.377	-1.000	2.229		-1.000	2.639	2.377

(Continued)

TABLE B-8. (CONTINUED)

DATE	INF	1	2	3	4	5	6
22	1.977	1.270	1.522		-1.000	1.647	2.087
29	5.097	3.165	3.611		-1.000	-1.000	3.851
JUN 5	4.866	2.348	2.835			-1.000	2.420
12	3.080	2.360	-1.000			2.774	2.682
19	2.871	3.157	-1.000			-1.000	2.514
26	3.404	3.263	-1.000			-1.000	3.754

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-9. FILTER EFFLUENT COMPARISONS AND REMOVAL EFFICIENCIES FOR ORTHOPHOSPHATE AS PHOSPHORUS

DATA COMPARISON FOR ORTHO P (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	3.192	1.442	2.981	3.091	3.096	3.192	3.404
12	1.760	1.314	1.672	1.697	1.665	1.854	1.848
15	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
17	1.928	1.250	1.536	1.464	1.536	1.536	1.714
18	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
19	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
[illegible]	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
24	2.059	1.530	1.094	1.802	1.824	1.581	1.640
26	-5.000	-5.000	-5.000	-5.000	-5.000	-1.000	-5.000
31	2.076	1.861	1.961	1.769	-1.000	-1.000	-5.000
AUG 6	-5.000	-5.000	-5.000	-1.000	-1.000	-1.000	-5.000
7	0.959	1.335	1.226	-1.000	-1.000	-1.000	1.576
14	0.985	-1.000	1.185	1.259	1.222	1.222	-5.000
16	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
19	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
21	1.054	-1.000	0.878	-1.000	-1.000	-1.000	1.229
SEP 4	0.954	1.227	0.901	1.022	1.045	-5.000	1.272
6	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
9	-5.000	-5.000	-5.000	-5.000	-1.000	-5.000	-5.000
11	1.071	0.805	0.906	1.136	-1.000	0.971	1.079
18	1.139	0.805	-1.000	0.799	1.048	1.118	0.951
20	-5.000	-5.000	-1.000	-5.000	-5.000	-5.000	-5.000
26	1.909	1.209	1.028	1.378	1.555	1.496	1.189
OCT 3	2.222	1.777	1.866	2.014	2.132	2.207	1.792
10	1.933	2.396	2.239	2.463	2.448	2.500	2.321
17	2.090	2.285	1.955	2.210	-1.000	-1.000	2.330
24	1.880	1.872	-1.000	-1.000	2.057	2.084	2.035
31	1.915	1.660	-5.000	-1.000	-1.000	-1.000	2.070
NOV 7	2.223	-1.000	2.238	-1.000	-1.000	-1.000	2.261
14	2.173	2.043	2.317		2.129	2.043	2.388
21	2.151	2.179	2.165		-1.000	-1.000	2.423
28	2.372	2.561	2.530		-1.000	-1.000	2.704
DEC 5	2.264	2.385	-1.000		-1.000	-1.000	2.551
12	2.137	2.236	-1.000		-1.000	-1.000	2.206
19	2.175	2.219	-1.000		-1.000	-1.000	2.307
26	2.564	2.548	-1.000		2.501	2.811	2.517
JAN 2	2.774	2.605	2.881		2.759	2.728	2.759
9	2.863	2.835	2.863		2.676	2.691	2.705
16	3.127	2.793	3.025		2.982	2.909	2.967
23	3.529	3.468	3.361		3.422	3.574	3.361
30	3.393	3.393	3.096		3.081	3.481	3.220

(Continued)

TABLE B-9. (CONTINUED)

DATE	INF	1	2	3	4	5	6
FEB 6	3.422	3.422	3.240		3.361	3.513	3.270
13	3.109	3.093	2.766		3.152	3.123	2.795
20	2.477	2.879	2.727		2.955	-1.000	2.500
27	2.702	3.022	2.611		3.176	-1.000	2.824
MAR 6	2.758	2.909	2.606		5.227	3.182	2.848
13	2.097	2.547	2.367		2.831	2.951	-1.000
20	2.446	2.308	2.538		2.800	2.692	-1.000
27	2.467	-1.000	-1.000		2.773	-1.000	-1.000
APR 3	2.374	-1.000	-1.000		2.715	-1.000	2.195
10	2.508	2.133	-1.000		2.569	-1.000	2.400
17	2.542	2.310	1.300		2.412	-1.000	2.570
24	2.813	3.034	2.529		2.513	-1.000	2.924
MAY 1	2.689	2.672	-1.000		2.689	3.164	2.902
8	2.336	2.288	-1.000		2.480	-1.000	2.672
15	1.902	-1.000	2.262		-1.000	2.656	2.328
22	1.412	1.318	1.412		-1.000	1.616	2.055
29	3.407	3.006	3.559		-1.000	-1.000	3.559
JUN 5	2.084	2.230	2.506			-1.000	2.417
12	2.428	2.272	-1.000			2.615	2.661
19	2.428	2.871	-1.000			-1.000	3.043
26	3.193	2.895	-1.000			-1.000	3.456

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-10. FILTER EFFLUENT COMPARISONS AND REMOVAL EFFICIENCIES FOR AMMONIA AS NITROGEN

DATA COMPARISON FOR NH3-N (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	3.370	2.538	1.637	1.171	1.150	1.378	0.224
12	1.877	0.456	0.474	0.156	0.392	0.262	0.452
15	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
17	3.378	0.231	0.385	0.518	0.725	0.665	0.040
18	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
19	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
22	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
24	3.359	0.081	0.058	0.120	0.340	0.697	0.121
26	-5.000	-5.000	-5.000	-5.000	-5.000	-1.000	-5.000
31	2.499	0.136	0.316	0.490	-1.000	-1.000	-5.000
AUG 6	-5.000	-5.000	-5.000	-1.000	-1.000	-1.000	-5.000
7	1.233	0.082	0.231	-1.000	-1.000	-1.000	0.052
14	0.168	-1.000	0.113	0.092	0.073	0.130	-5.000
16	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
19	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
21	0.091	-1.000	0.135	-1.000	-1.000	-1.000	0.044
SEP 4	0.120	0.130	0.111	0.072	0.098	0.152	0.064
6	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
9	-5.000	-5.000	-5.000	-5.000	-1.000	-5.000	-5.000
11	0.395	0.125	0.080	0.030	-1.000	0.111	0.025
18	0.820	0.140	-1.000	0.063	-5.000	0.068	0.020
20	-5.000	-5.000	-1.000	-5.000	-5.000	-5.000	-5.000
26	2.259	0.222	0.423	0.054	0.529	0.145	0.045

(Continued)

TABLE B-10. (CONTINUED)

DATE	INF	1	2	3	4	5	6
OCT 3	4.602	0.951	0.588	0.310	0.160	0.575	0.036
10	3.832	0.176	0.559	0.374	0.311	0.374	0.040
17	1.906	0.193	0.315	0.081	-1.000	-1.000	0.071
24	2.516	0.089	-1.000	-1.000	0.087	0.097	0.048
31	2.378	0.396	-5.000	-1.000	-1.000	-1.000	0.066
NOV 7	6.287	-1.000	0.551	-1.000	-1.000	-1.000	0.145
14	2.693	0.774	2.434		0.264	0.360	0.166
21	5.460	1.029	0.808		-1.000	-1.000	0.573
26	4.407	0.842	1.314		-1.000	-1.000	0.539
DEC 5	3.841	0.728	-1.000		-1.000	-1.000	0.748
12	3.769	0.779	-1.000		-1.000	-1.000	0.966
19	4.896	0.782	-1.000		-1.000	-1.000	1.330
26	6.581	0.744	-1.000		2.710	2.436	1.214
JAN 2	4.916	0.983	2.240		2.257	2.531	1.830
9	3.118	1.708	3.168		2.703	2.550	2.478
16	6.650	2.923	5.992		4.073	3.749	3.538
23	7.621	2.326	7.061		3.084	3.101	2.546
30	5.656	1.283	6.622		3.189	2.694	3.204
FEB 6	6.059	0.746	5.911		2.373	1.754	2.254
13	5.418	0.628	6.068		0.699	2.595	3.181
20	4.687	0.376	4.129		0.473	-1.000	2.058
27	3.998	0.675	4.602		0.362	-1.000	1.790
MAR 6	4.200	1.098	4.822		0.238	0.201	1.689
13	2.858	0.901	1.413		0.433	0.054	-1.000
20	5.732	0.548	3.285		0.506	0.153	-1.000
27	5.793	-1.000	-1.000		0.708	-1.000	-1.000
APR 3	1.710	-1.000	-1.000		0.213	-1.000	0.451
10	2.466	0.285	-1.000		0.517	-1.000	0.102
17	4.011	1.122	0.690		1.081	-1.000	0.181
24	4.582	0.909	0.894		1.085	-1.000	0.107
MAY 1	2.811	0.500	-1.000		0.346	0.092	0.069
8	1.999	0.258	-1.000		0.275	-1.000	0.069
15	1.804	-1.000	0.225		-1.000	0.221	0.072
22	1.060	0.145	0.163		-1.000	0.275	0.120
29	1.864	0.105	0.244		-1.000	-1.000	0.040
JUN 5	2.302	0.226	1.252			-1.000	0.052
12	3.296	0.294	-1.000			0.062	0.115
19	2.361	0.333	-1.000			-1.000	0.040
26	4.530	0.426	-1.000			-1.000	0.022

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-11. FILTER EFFLUENT COMPARISONS AND REMOVAL EFFICIENCIES FOR NITRITE AS NITROGEN

DATA COMPARISON FOR NO2-N (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	0.174	1.040	0.982	0.796	0.747	0.790	0.092
12	0.022	0.058	0.191	0.227	0.395	0.303	0.063
15	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
17	0.019	0.018	0.018	0.052	0.074	0.133	-5.000
18	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	0.124
19	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
22	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
24	0.027	0.007	0.012	0.015	0.008	0.025	-5.000
26	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	0.022
31	0.027	0.031	0.040	0.066	-1.000	-1.000	-5.000
AUG 6	-5.000	-5.000	-5.000	-1.000	-1.000	-1.000	-5.000
7	0.029	0.011	0.015	-1.000	-1.000	-1.000	-5.000
14	0.007	-1.000	0.015	0.009	0.004	0.019	0.124
16	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
19	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
21	0.002	-1.000	0.008	-1.000	-1.000	-1.000	-5.000
SEP 4	0.001	0.025	0.016	0.035	0.036	-1.000	0.004
6	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	0.032
9	-5.000	-5.000	-5.000	-5.000	-1.000	-5.000	-5.000
11	0.006	0.244	0.075	0.020	-1.000	-5.000	-5.000
18	0.017	0.155	-1.000	0.172	-1.000	0.108	0.157
20	-5.000	-5.000	-1.000	-5.000	0.084	0.174	0.150
26	0.014	0.045	0.054	0.038	-5.000	-5.000	-5.000
OCT 3	0.015	0.245	0.044	0.069	0.401	0.048	0.016
10	0.013	0.012	0.204	0.106	0.093	0.162	0.000
17	0.039	0.008	0.076	0.040	0.168	0.451	0.032
24	0.055	0.070	-1.000	-1.000	-1.000	-1.000	0.017
31	0.042	0.039	-5.000	-1.000	0.065	0.117	0.005
NOV 7	0.042	-1.000	0.163	-1.000	-1.000	-1.000	0.027
14	0.037	0.196	0.237		-1.000	-1.000	0.068
21	0.034	0.164	0.540		0.214	0.461	0.083
26	0.020	0.021	0.010		-1.000	-1.000	0.545
DEC 5	0.035	0.140	-1.000		-1.000	-1.000	0.017
12	0.029	0.023	-1.000		-1.000	-1.000	0.221
19	0.034	0.028	-1.000		-1.000	-1.000	0.054
26	0.029	0.043	-1.000		-1.000	-1.000	0.036
JAN 2	0.027	0.034	0.092		0.106	0.040	0.032
9	0.032	0.019	0.072		0.275	0.055	0.040
16	0.021	0.031	0.016		0.590	0.510	0.010
23	0.002	0.026	0.012		0.133	0.229	0.010
30	0.003	0.024	0.016		0.202	0.057	0.011
FEB 6	0.006	0.017	0.015		0.030	0.028	0.010
13	0.023	0.090	0.018		0.021	0.010	0.010
20	0.006	0.010	0.026		0.197	0.059	0.078
27	0.011	0.018	0.025		0.010	-1.000	0.015
MAR 6	0.014	0.019	0.056		0.029	-1.000	0.011
13	0.014	0.021	0.058		0.015	0.026	0.011
20	0.029	0.019	0.041		0.015	0.004	-1.000
27	0.042	-1.000	-1.000		0.012	0.003	-1.000
APR 3	0.032	-1.000	-1.000		0.019	-1.000	-1.000
10	0.040	0.015	-1.000		0.012	-1.000	0.020
17	0.043	0.043	0.144		0.017	-1.000	0.004
24	0.051	0.055	0.182		0.040	-1.000	0.009
MAY 1	0.069	0.066	-1.000		0.052	-1.000	0.013
8	0.077	0.060	-1.000		0.046	0.014	0.010
15	0.083	-1.000	0.033		0.042	-1.000	0.003
					-1.000	0.059	0.014

(Continued)

TABLE B-11. (CONTINUED)

DATE	INF	1	2	3	4	5	6
22	0.083	0.015	0.013		-1.000	0.091	0.003
29	0.072	0.043	0.107		-1.000	-1.000	0.005
JUN 5	0.059	0.149	0.098			-1.000	0.006
12	0.013	0.104	-1.000			0.015	0.015
19	0.019	0.104	-1.000			-1.000	0.010
26	0.033	0.023	-1.000			-1.000	0.013

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

TABLE B-12. FILTER EFFLUENT COMPARISONS AND REMOVAL EFFICIENCIES FOR NITRATE AS NITROGEN

DATA COMPARISON FOR NO3-N (MG/L)

DATE	INF	1	2	3	4	5	6
JUL 2	0.784	0.791	1.823	1.079	1.830	0.718	3.676
12	0.166	2.130	8.702	3.198	1.189	1.167	7.978
15	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
17	0.121	8.933	9.359	9.425	8.490	7.022	12.512
18	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
19	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
22	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
24	0.054	2.027	1.704	1.701	1.312	1.955	3.509
26	-5.000	-5.000	-5.000	-5.000	-5.000	-1.000	-5.000
31	0.054	5.136	4.329	3.165	-1.000	-1.000	-5.000
AUG 6	-5.000	-5.000	-5.000	-1.000	-1.000	-1.000	-5.000
7	0.084	1.453	0.832	-1.000	-1.000	-1.000	2.524
14	0.043	-1.000	1.704	2.130	1.067	1.402	-5.000
16	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
19	-5.000	-1.000	-5.000	-5.000	-1.000	-1.000	-5.000
21	0.116	-1.000	0.656	-1.000	-1.000	-1.000	1.032
SEP 4	0.020	3.609	2.868	1.089	2.567	4.898	6.870
6	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000	-5.000
9	-5.000	-5.000	-5.000	-5.000	-1.000	-5.000	-5.000
11	0.046	1.751	3.440	1.469	-1.000	2.761	2.313
18	0.072	2.709	-1.000	2.347	1.966	2.836	3.013
20	-5.000	-5.000	-1.000	-5.000	-5.000	-5.000	-5.000
26	0.037	1.613	2.863	2.484	4.653	3.111	4.664
OCT 3	0.031	3.199	4.010	3.627	2.728	3.934	5.888
10	0.067	4.910	6.474	5.857	3.518	5.532	6.009
17	0.140	6.201	3.501	5.671	-1.000	-1.000	5.877
24	0.052	4.510	-1.000	-1.000	3.877	4.737	5.396
31	0.166	0.897	-5.000	-1.000	-1.000	-1.000	5.103
NOV 7	0.112	-1.000	5.894	-1.000	-1.000	-1.000	4.349
14	0.196	7.746	2.423		6.110	11.071	5.174
21	0.113	6.261	9.541		-1.000	-1.000	4.962
28	0.102	4.940	2.121		-1.000	-1.000	2.909
DEC 5	0.203	10.398	-1.000		-1.000	-1.000	7.033
12	0.171	6.707	-1.000		-1.000	-1.000	3.781
19	0.165	5.245	-1.000		-1.000	-1.000	3.422
26	0.204	5.993	-1.000		3.230	3.232	3.950

(Continued)

TABLE B-12. (CONTINUED)

DATE	INF	1	2	3	4	5	6
JAN 2	0.134	6.406	5.136		4.095	3.788	4.000
9	0.105	4.946	3.845		6.786	2.714	7.377
16	0.052	8.134	0.244		3.933	5.884	0.927
23	0.020	5.945	0.806		6.612	5.604	1.355
30	0.019	6.586	0.078		3.376	3.455	1.267
FEB 6	0.028	3.655	0.105		3.517	2.509	1.659
13	0.042	5.199	0.058		10.431	1.125	1.970
20	0.053	1.088	0.078		6.530	-1.000	1.735
27	0.099	5.850	0.271		9.578	-1.000	2.889
MAR 6	0.085	0.817	0.123		4.285	5.153	0.673
13	0.077	0.791	0.694		2.042	1.242	-1.000
20	0.180	0.940	0.933		1.424	0.580	-1.000
27	0.122	-1.000	-1.000		1.358	-1.000	-1.000
APR 3	0.214	-1.000	-1.000		1.412	-1.000	5.848
10	0.220	0.948	-1.000		1.661	-1.000	4.046
17	0.199	1.100	9.657		2.010	-1.000	7.133
24	0.151	1.522	7.722		2.162	-1.000	5.930
MAY 1	0.283	1.581	-1.000		2.270	5.137	5.856
8	0.431	1.347	-1.000		1.888	-1.000	4.097
15	0.402	-1.000	4.933		-1.000	7.813	8.864
22	0.571	5.186	3.064		-1.000	1.741	3.843
29	0.260	6.750	4.909		-1.000	-1.000	5.538
JUN 5	0.200	7.030	0.403			-1.000	6.628
12	0.037	5.485	-1.000			5.238	7.123
19	0.047	5.911	-1.000			-1.000	8.342
26	0.095	10.088	-1.000			-1.000	6.671

* NOTE: -1.0 INDICATES A PLUGGED FILTER AND -5.0 INDICATES MISSING DATA

Appendix C

1. The Pounds Removed by Each Filter for Weekly and Total Run Periods.
2. Run Comparisons Between Filters in Pounds Removed for Each Parameter.
3. Seasonal Filter Comparisons in Pounds Removed for Each Parameter.

1 MGAD = 9354 m^3/hectare-day
1 Pound= 0.454 kg

TABLE C-1-1. REMOVAL DATA FOR FILTER 1

REMOVAL DATA FOR FILTER 1

RUN	NUMBER DAYS	LOADING (MGAD)	DATE	POUNDS REMOVED								
				BOD5	COD	SS	VSS	TOTAL P	O-PO4-P	NH3-N	NO2-N	NO3-N
	6.	0.5	JUL 2	0.57	6.21	4.24	1.34	0.88	0.91	0.43	-0.45	-0.00
	3.	0.4	12	1.86	14.89	-1.22	2.96	0.45	0.15	0.48	-0.01	-2.35
	2.	0.4	15	-5.00	-5.00	0.80	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.4	17	5.27	1.22	0.16	3.69	-5.00	0.14	0.64	0.00	-1.79
	1.	0.4	18	-5.00	-5.00	-0.11	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.4	19	-5.00	-5.00	-0.39	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	0.4	22	-5.00	-5.00	2.10	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	0.4	24	1.13	73.36	1.70	2.86	0.57	0.57	3.54	0.02	-2.13
	5.	0.4	26	-5.00	-5.00	7.29	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	6.	0.4	31	6.14	18.29	6.12	5.01	0.21	0.10	1.12	-0.00	-2.40
	1.	0.4	AUG 6	-5.00	-5.00	4.73	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.4	7	0.29	3.58	2.46	1.97	0.03	-0.03	0.08	0.00	-0.09
1	33	0.4	7/2-8/7	15.27	117.54	27.97	17.83	2.13	1.84	6.28	-0.44	-8.77
	0.	P	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.	0.4	SEP 4	2.12	29.54	5.42	4.78	0.20	-0.13	-0.00	-0.01	-1.66
	3.	0.4	6	-5.00	-5.00	7.74	5.12	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	0.4	9	1.08	-5.00	4.19	3.47	-5.00	-5.00	-5.00	-5.00	-5.00
	7.	0.4	11	2.04	19.56	12.73	8.89	0.30	0.12	0.13	-0.11	-0.79
	2.	0.4	18	0.74	11.33	1.68	1.06	0.34	0.18	0.36	-0.07	-1.40
	6.	0.4	20	3.02	-5.00	5.00	3.02	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	0.4	26	0.54	2.30	4.39	2.24	0.19	0.14	0.40	-0.01	-0.31

(Continued)

TABLE C-1-1. (CONTINUED)

2	25	0.4	9/4-9/28	9.53	63.13	41.16	28.57	1.04	0.31	0.88	-0.20	-4.16
	8.	0.4	OCT 3	2.43	8.94	7.83	3.12	0.33	0.24	1.93	-0.12	-1.68
	7.	0.4	10	2.96	10.74	10.14	5.00	0.12	-0.21	1.69	0.00	-2.24
	7.	0.4	17	4.26	11.48	12.13	3.80	0.01	-0.09	0.79	0.01	-2.81
	6.	0.4	24	6.99	21.59	16.75	13.22	0.27	0.00	0.56	-0.01	-1.77
	3.	0.4	31	3.95	5.76	6.47	4.90	0.20	0.05	0.39	0.00	-0.15
3	31	0.4	10/2-11/3	20.59	58.52	53.33	30.04	0.93	-0.02	5.78	-0.11	-8.64
	0.	P	NOV 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	8.	0.4	14	9.84	14.77	20.80	15.08	0.35	0.07	1.02	-0.08	-4.00
	5.	0.4	21	2.32	6.48	7.08	3.61	-0.01	-0.01	1.47	-0.04	-2.03
	9.	0.4	26	7.09	15.60	18.46	10.36	0.00	-0.11	2.12	-0.00	-2.88
	7.	0.4	DEC 5	8.24	15.74	10.10	7.92	0.01	-0.06	1.44	-0.05	-4.72
	7.	0.4	12	9.59	21.16	13.20	11.72	0.16	-0.05	1.38	0.00	-3.03
	7.	0.4	19	3.80	9.56	5.97	4.82	0.05	-0.02	1.51	0.00	-2.35
	7.	0.4	26	7.09	25.61	8.29	7.27	0.11	0.01	2.70	-0.01	-2.68
	7.	0.4	JAN 2	3.29	9.77	3.57	2.78	0.09	0.08	1.82	-0.00	-2.90
	7.	0.4	9	1.67	8.52	1.99	1.34	0.09	0.01	0.65	0.01	-2.24
	7.	0.4	16	4.49	14.26	4.54	2.64	0.16	0.15	1.73	-0.00	-3.74
	7.	0.4	23	4.26	14.45	5.23	4.45	0.14	0.03	2.45	-0.01	-2.74
	7.	0.4	30	5.65	22.69	10.23	9.17	0.13	0.00	2.03	-0.01	-3.04
	7.	0.4	FEB 6	10.60	22.83	11.39	10.84	0.24	0.00	2.46	-0.01	-1.68
	7.	0.4	13	8.34	28.34	15.74	15.74	0.21	0.01	2.22	-0.03	-2.39
	7.	0.4	20	10.28	25.93	17.83	17.09	0.45	-0.19	2.00	-0.00	-0.48
	7.	0.4	27	8.66	26.12	14.49	14.22	0.21	-0.15	1.54	-0.00	-2.66
	7.	0.4	MAR 6	5.74	30.52	17.27	15.88	-0.58	-0.07	1.44	-0.00	-0.34
	7.	0.4	13	5.65	22.09	15.56	14.40	0.04	-0.21	0.91	-0.00	-0.33
	3.	0.4	20	3.23	11.85	9.88	8.18	0.13	0.03	1.03	0.00	-0.15
4	130	0.4	11/13-3/22	119.82	346.69	211.63	177.49	1.59	-0.47	32.30	-0.24	-44.39
	0.	P	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	APR 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12.	0.4	10	8.26	31.67	19.05	12.78	0.56	0.30	1.73	0.02	-0.58
	5.	0.4	17	2.55	11.38	6.78	3.41	0.19	0.08	0.56	0.00	-0.30
	7.	0.4	24	9.86	13.89	11.35	5.42	0.26	-0.10	1.70	-0.00	-0.63
	7.	0.4	MAY 1	3.43	16.53	14.63	9.96	0.12	0.01	1.07	0.00	-0.60
	3.	0.4	8	2.28	9.72	8.51	5.36	0.13	0.01	0.35	0.00	-0.18

(Continued)

TABLE C-1-1. (CONTINUED)

5	34	0.4	4/5-5/10	26.38	83.20	60.33	36.92	1.26	0.29	5.80	0.02	-2.29
	0.	P	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.	0.4	22	3.20	17.76	4.80	2.91	0.51	0.07	0.67	0.05	-3.36
	7.	0.4	29	21.95	58.02	40.01	31.67	0.85	0.19	0.81	0.01	-3.01
	7.	0.4	JUN 5	132.81	197.04	59.83	50.29	1.17	-0.07	0.56	-0.04	-3.16
	6.	0.4	12	2.70	10.36	7.34	5.91	0.29	0.06	1.19	-0.04	-2.16
	7.	0.4	19	2.22	15.74	5.14	2.36	-0.13	-0.21	0.54	-0.04	-2.72
	2.	0.4	26	1.03	7.16	3.23	2.16	0.02	0.04	0.54	0.00	-1.32
6	40*	0.4	5/17-6/27	163.92	306.08	120.35	95.31	2.75	0.08	5.12	-0.05	-15.73

* NOTE: -5.0 INDICATES MISSING DATA

TABLE C-1-2. REMOVAL DATA FOR FILTER 2

RUN	NUMBER DAYS	LOADING (MGAD)	DATE	POUNDS REMOVED BOD5	COD	SS	VSS	TOTAL P	O-PO4-P	NH3-N	NO2-N	NO3-N
	6.	0.8	JUL 2	1.01	7.76	5.97	1.40	0.21	0.16	1.34	-0.63	-0.81
	3.	0.6	12	2.12	18.48	-1.36	3.90	0.13	0.04	0.68	-0.06	-4.11
	2.	0.6	15	-5.00	-5.00	0.77	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.6	17	5.81	51.12	-1.19	3.71	-5.00	0.34	2.59	0.00	-8.00
	1.	0.6	18	-5.00	-5.00	-0.14	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.6	19	-5.00	-5.00	-1.32	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	0.6	22	-5.00	-5.00	1.43	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	0.6	24	1.54	28.34	2.25	4.54	0.34	0.74	2.54	0.01	-1.27
	5.	0.6	26	-5.00	-5.00	10.01	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	6.	0.6	31	7.39	20.68	8.43	6.35	0.13	0.07	1.26	-0.01	-2.47
1	31	0.6	7/2-8/5	17.87	126.39	24.86	19.90	0.81	1.36	8.42	-0.70	-16.66
	0.	0.6	AUG 6	-5.00	-5.00	0.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	0.	0.6	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.	0.6	14	3.74	20.55	4.50	3.75	0.18	-0.08	0.02	-0.00	-0.64
	3.	0.6	16	-5.00	-5.00	13.83	10.20	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	0.6	19	-5.00	-5.00	9.34	7.41	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	0.6	21	2.04	24.53	10.19	6.55	0.36	0.07	-0.02	-0.00	-0.21
2	8	0.6	8/14-8/22	5.78	45.48	37.85	27.90	0.55	-0.01	0.00	-0.01	-0.85
	2.	0.6	SEP 4	3.57	41.81	6.84	7.02	0.55	0.04	0.01	-0.01	-1.95
	3.	0.6	6	-5.00	-5.00	11.76	7.74	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	0.6	9	1.62	-5.00	6.00	4.93	-5.00	-5.00	-5.00	-5.00	-5.00
	5.	0.6	11	2.74	23.81	13.93	9.48	0.33	0.08	0.15	-0.03	-1.66
3	12	0.6	9/4-9/15	7.93	65.62	38.54	29.17	0.88	0.12	0.16	-0.04	-3.61
	0.	P	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.	0.6	26	1.30	4.72	9.17	6.98	0.69	0.60	1.26	-0.03	-1.93
	7.	0.6	OCT 3	3.42	12.73	10.13	3.90	0.39	0.24	2.75	-0.02	-2.72
	7.	0.6	10	4.79	15.26	14.44	7.46	0.34	-0.21	2.24	-0.13	-4.38
	6.	0.6	17	4.93	14.66	15.37	4.87	0.06	0.08	0.53	-0.02	-1.97
4	27	0.6	9/26-10/22	14.44	47.38	49.11	23.21	1.47	0.72	7.18	-0.20	-11.01
	0.	P	24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	0.6	31	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	7.	0.6	NOV 7	7.66	14.71	15.74	11.50	0.48	-0.01	3.93	-0.08	-3.96
	9.	0.6	14	16.28	33.79	34.23	24.99	0.29	-0.13	0.23	-0.18	-1.96

(Continued)

TABLE C-1-2. (CONTINUED)

5	16	0.6	10/31-11/16	23.94	48.50	49.92	36.49	0.77	-0.14	4.15	-0.26	-5.92
	6.	0.6	21	4.16	11.91	11.85	6.04	-0.01	-0.01	2.73	-0.30	-5.53
	8.	0.6	26	8.99	18.54	23.54	13.30	0.04	-0.12	2.42	0.01	-1.58
6	14	0.6	11/20-12/4	13.16	30.44	35.39	19.34	0.03	-0.13	5.15	-0.29	-7.11
	0.	P	DEC 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	8.	0.4	JAN 2	1.30	5.68	1.98	1.72	0.02	-0.06	1.40	-0.03	-2.61
	7.	0.4	9	1.46	6.66	0.59	1.28	0.11	0.00	-0.02	-0.02	-1.71
	7.	0.4	16	2.92	8.71	2.78	2.42	0.04	0.05	0.30	0.00	-0.09
	7.	0.4	23	0.96	7.39	3.74	3.70	0.13	0.08	0.26	-0.00	-0.36
	7.	0.4	30	4.70	11.91	6.43	6.48	0.14	0.14	-0.44	-0.01	-0.03
	7.	0.4	FEB 6	8.71	15.28	9.12	9.17	0.26	0.08	0.07	-0.00	-0.04
	7.	0.4	13	4.06	13.73	9.63	11.22	0.22	0.16	-0.30	0.00	-0.01
	5.	0.4	20	4.14	12.32	9.87	9.58	0.38	-0.08	0.18	-0.01	-0.01
	3.	0.4	27	2.72	7.63	5.16	5.12	0.09	0.02	-0.12	-0.00	-0.03
	6.	0.4	MAR 6	1.09	18.03	12.91	11.97	-0.60	0.06	-0.24	-0.02	-0.01
	7.	0.4	13	3.56	21.08	13.41	12.64	0.09	-0.12	0.66	-0.02	-0.28
	2.	0.4	20	1.72	6.35	5.23	4.26	0.08	-0.01	0.32	-0.00	-0.10
7	73	0.4	1/1-3/21	37.35	134.77	80.87	79.56	0.56	0.30	2.06	-0.11	-5.27
	0.	P	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	APR 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.	0.6	17	4.04	25.73	12.32	6.30	0.51	0.85	2.27	-0.07	-6.47
	6.	0.6	24	11.38	19.94	13.14	6.16	0.35	0.17	2.16	-0.08	-4.44
8	13	0.6	4/15-4/29	15.42	45.68	25.46	12.46	1.26	1.02	4.44	-0.15	-10.91
	0.	P	MAY 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.	0.6	15	5.47	19.85	11.36	8.42	0.10	-0.25	1.08	0.03	-3.10
	7.	0.6	22	2.74	16.70	4.11	2.81	0.31	0.00	0.61	0.05	-1.71
	7.	0.6	29	31.89	83.50	58.44	46.54	1.02	-0.10	1.11	-0.02	-3.18
	4.	0.6	JUN 5	110.20	161.00	49.90	42.04	0.79	-0.17	0.41	-0.02	-0.08
9	25	0.6	5/14-6/8	150.31	281.45	123.81	99.80	2.22	-0.52	3.21	0.04	-8.07

* NOTE: -5.0 INDICATES MISSING DATA

TABLE C-1-3. REMOVAL DATA FOR FILTER 3

RUN	NUMBER DAYS	LOADING (MGAD)	DATE	POUNDS REMOVED								
				BOD5	COD	SS	VSS	TOTAL P	O-PO4-P	NH3-N	NO2-N	NO3-N
	8.	1.0	JUL 2	1.24	-2.76	11.86	2.90	0.80	0.14	3.03	-0.86	-0.41
	3.	0.8	12	3.02	5.67	5.74	6.98	0.10	0.05	1.27	-0.15	-2.23
	2.	0.8	15	-5.00	-5.00	1.56	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.8	17	6.60	72.14	-1.15	4.51	-5.00	0.48	2.95	-0.03	-9.59
	1.	0.8	18	-5.00	-5.00	-0.72	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.8	19	-5.00	-5.00	-3.31	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	0.8	22	-5.00	-5.00	1.16	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	0.8	24	2.24	14.61	3.14	6.83	0.48	0.30	3.82	0.01	-1.94
	5.	0.8	26	-5.00	-5.00	15.68	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.8	31	1.69	4.65	2.13	1.53	0.08	0.05	0.30	-0.01	-0.46
1	28	0.8	7/2-7/31	14.79	94.31	36.09	22.74	1.47	1.01	11.36	-1.03	-14.63
	0.	P	AUG 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.	0.8	14	8.75	50.35	11.60	11.40	0.29	-0.24	0.07	-0.00	-1.84
	2.	0.8	16	-5.00	-5.00	14.19	10.04	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	0.8	19	-5.00	-5.00	13.72	11.16	-5.00	-5.00	-5.00	-5.00	-5.00
2	6	0.8	8/14-8/20	8.75	50.35	39.52	32.60	0.29	-0.24	0.07	-0.00	-1.84
	0.	P	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.	0.8	SEP 4	4.97	59.15	10.55	9.68	0.75	-0.06	0.05	-0.03	-1.02
	3.	0.8	6	-5.00	-5.00	15.82	9.85	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	0.8	9	2.62	-5.00	8.37	6.79	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	0.8	11	1.50	13.93	7.69	5.34	0.19	-0.02	0.10	-0.00	-0.39
3	9	0.8	9/4-9/12	9.09	73.08	42.43	31.66	0.54	-0.08	0.15	-0.04	-1.41
	2.	0.8	18	1.14	12.21	2.26	1.99	0.61	0.37	0.83	-0.17	-2.48
	6.	0.8	20	5.89	-5.00	9.57	6.38	-5.00	-5.00	-5.00	-5.00	-5.00
	7.	0.8	26	2.96	15.93	20.32	10.69	0.79	0.51	2.10	-0.02	-2.33
	4.	0.8	OCT 3	3.05	9.32	7.91	3.00	0.21	0.11	2.34	-0.03	-1.96
4	19	0.8	9/18-10/6	13.04	37.47	40.06	22.05	1.61	0.59	5.27	-0.22	-6.78
	8.	0.8	10	6.54	24.10	23.55	11.67	0.34	-0.58	3.77	-0.10	-6.31
	5.	0.8	17	4.84	17.65	18.20	5.79	0.10	-0.08	1.24	-0.00	-3.77
5	13	0.8	10/9-10/21	11.38	41.75	41.75	17.46	0.44	-0.66	5.01	-0.10	-10.08

* NOTE: -5.0 INDICATES MISSING DATA

TABLE C-1-4. REMOVAL DATA FOR FILTER 4

RUN	NUMBER DAYS	LOADING (MGAD)	DATE	POUNDS REMOVED								
				BOD5	COD	SS	VSS	TOTAL P	O-PO4-P	NH3-N	NO2-N	NO3-N
	8.	1.3	JUL 2	0.17	24.14	13.62	2.59	0.97	0.17	3.83	-0.99	-1.80
	3.	1.0	12	2.99	27.82	7.07	8.09	0.19	0.08	1.27	-0.32	-0.87
	2.	1.0	15	-5.00	-5.00	0.10	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	1.0	17	6.25	14.34	-1.45	2.65	-5.00	0.40	2.72	-0.06	-8.57
	1.	1.0	18	-5.00	-5.00	0.22	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	1.0	19	-5.00	-5.00	-1.71	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	1.0	22	-5.00	-5.00	-0.17	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	1.0	24	2.63	75.52	3.48	9.90	0.31	0.28	3.61	0.02	-1.50
	4.	1.0	26	-5.00	-5.00	13.72	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
1	26	1.0	7/2-7/29	12.04	141.82	34.89	23.22	1.47	0.93	11.42	-1.34	-12.75
	0.	P	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	AUG 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3.	1.0	14	4.87	25.45	20.74	19.97	0.20	-0.12	0.05	0.00	-0.52
2	3	1.0	8/14-8/16	4.87	25.45	20.74	19.97	0.20	-0.12	0.05	0.00	-0.52
	0.	P	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.	1.0	SEP 4	4.66	40.74	11.74	10.69	0.43	-0.06	0.02	-0.02	-1.67
	2.	1.0	6	-5.00	-5.00	12.96	8.40	-5.00	-5.00	-5.00	-5.00	-5.00
3	4	1.0	9/4-9/7	4.66	40.74	24.70	19.09	0.43	-0.06	0.02	-0.02	-1.67
	0.	P	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	8.	1.0	18	4.59	14.69	5.90	7.61	0.60	0.12	-5.00	-0.09	-2.48
	-5.	1.0	20	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	1.0	26	0.82	2.69	7.05	3.74	0.24	0.11	2.84	-0.13	-1.51
4	10	1.0	9/18-9/27	5.41	17.38	12.96	11.35	0.85	0.23	2.84	-0.21	-4.00
	5.	1.0	OCT 3	4.43	14.92	11.64	4.51	0.16	0.07	3.64	-0.06	-2.21
5	5	1.0	10/2-10/6	4.43	14.92	11.64	4.51	0.16	0.07	3.64	-0.06	-2.21
	5.	1.0	10	5.33	15.83	17.30	8.61	0.29	-0.42	2.89	-0.13	-2.83

(Continued)

TABLE C-1-4. (CONTINUED)

6	5	1.0	10/9-10/13	5.33	15.83	17.30	8.61	0.29	-0.42	2.89	-0.13	-2.83
	0.	P	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.	1.0	24	17.81	50.18	40.44	31.88	0.28	-0.17	2.39	-0.01	-3.76
7	6	1.0	10/23-10/28	17.81	50.18	40.44	31.88	0.28	-0.17	2.39	-0.01	-3.76
	0.	P	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	NOV 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	8.	1.0	14	24.53	49.59	50.38	37.78	0.78	0.06	3.19	-0.23	-7.76
8	8	1.0	11/13-11/20	24.53	49.59	50.38	37.78	0.78	0.06	3.19	-0.23	-7.76
	0.	P	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	DEC 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.	0.4	26	9.31	39.06	10.82	10.30	0.19	0.04	2.54	-0.05	-1.98
	7.	0.4	JAN 2	2.89	10.56	2.85	2.62	-0.15	0.01	1.22	-0.11	-1.82
	7.	0.4	9	1.38	8.17	1.65	1.38	0.18	0.09	0.19	-0.26	-3.07
	7.	0.4	16	4.36	12.26	3.99	2.75	0.17	0.07	1.18	-0.05	-1.78
	7.	0.4	23	4.22	14.10	4.96	4.55	0.13	0.05	2.08	-0.09	-3.03
	7.	0.4	30	5.79	16.21	7.76	6.93	0.06	0.14	1.13	-0.01	-1.54
	7.	0.4	FEB 6	7.48	18.69	8.63	8.36	0.26	0.03	1.69	-0.01	-1.60
	7.	0.4	13	8.86	27.92	15.52	15.89	0.19	-0.02	2.17	-0.08	-4.77
	7.	0.4	20	10.79	25.16	17.17	16.58	0.42	-0.22	1.53	-0.00	-2.97
	7.	0.4	27	9.32	25.71	14.60	14.74	-0.05	-0.22	1.67	-0.01	-4.35
	7.	0.4	MAR 6	6.98	34.90	18.41	17.03	-1.41	-1.13	1.82	-0.00	-1.93
	7.	0.4	13	5.92	29.23	14.83	13.87	-0.10	-0.34	1.11	-0.00	-0.90
	7.	0.4	20	8.22	29.02	20.89	17.72	0.14	-0.16	2.40	0.01	-0.57
	7.	0.4	27	8.04	28.10	19.88	16.25	0.15	-0.13	2.33	0.01	-0.57
	7.	0.4	APR 3	8.77	30.40	20.02	16.02	0.13	-0.16	0.69	0.01	-0.55
	7.	0.4	10	5.88	19.53	10.70	7.39	0.12	-0.03	0.89	0.01	-0.66
	5.	0.4	17	2.69	10.82	6.03	2.98	0.14	0.04	0.96	0.00	-0.59
	7.	0.4	24	10.24	14.60	10.29	4.82	0.25	0.14	1.61	-0.00	-0.92
	7.	0.4	MAY 1	3.88	18.37	13.91	9.41	0.12	0.00	1.13	0.01	-0.91
	7.	0.4	8	5.19	19.88	18.60	11.62	0.17	-0.07	0.79	0.02	-0.67
9	141-	0.4	12/23-5/14	130.19	421.09	241.53	201.22	1.13	-1.87	29.55	-0.61	-35.20

* NOTE: -5.0 INDICATES MISSING DATA

TABLE C-1-5. REMOVAL DATA FOR FILTER 5

RUN	NUMBER DAYS	LOADING (MGAD)	DATE	POUNDS REMOVED								
				BOD5	COD	SS	VSS	TOTAL P	O-PO4-P	NH3-N	NO2-N	NO3-N
	8.	1.5	JUL 2	1.66	37.24	18.00	3.93	0.32	0.00	4.12	-1.27	0.14
	3.	1.2	12	3.20	34.12	9.60	8.21	0.39	-0.08	1.44	-0.25	-0.89
	2.	1.2	15	-5.00	-5.00	-3.45	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	1.2	17	2.24	-12.80	-1.35	3.38	-5.00	0.42	2.69	-0.12	-7.36
	1.	1.2	18	-5.00	-5.00	0.27	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	1.2	19	-5.00	-5.00	-0.78	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	1.2	22	-5.00	-5.00	1.27	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	1.2	24	0.57	20.69	3.48	5.69	0.20	0.17	0.55	0.00	-0.68
1	21	1.2	7/2-7/24	7.66	79.26	27.03	21.21	0.92	0.50	9.40	-1.65	-8.79
	0.	P	26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	AUG 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3.	1.2	14	5.44	28.90	23.09	20.74	0.21	-0.13	0.02	-0.01	-0.72
2	3	1.2	8/14-8/16	5.44	28.90	23.09	20.74	0.21	-0.13	0.02	-0.01	-0.72
	0.	P	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.	1.0	SEP 4	-5.00	65.37	11.67	10.49	0.67	-5.00	-0.03	-5.00	-4.92
	3.	1.0	6	-5.00	-5.00	17.73	11.24	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	1.0	9	7.97	-5.00	8.56	7.12	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	1.0	11	1.01	13.11	8.27	5.56	0.10	0.13	0.08	-0.13	-0.78
3	9	1.0	9/4-9/12	8.98	78.49	46.23	34.42	0.77	0.13	0.05	-0.13	-5.70
	2.	1.0	18	1.24	12.22	2.28	2.22	0.37	0.02	0.87	-0.18	-3.19
	6.	1.0	20	6.31	-5.00	9.34	6.14	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	1.0	26	0.89	2.59	6.20	3.17	0.19	0.12	0.61	-0.01	-0.89
4	10	1.0	9/18-9/27	8.45	14.82	17.81	11.53	0.56	0.14	1.48	-0.19	-4.07
	5.	1.0	OCT 3	3.89	15.49	10.66	3.89	0.15	0.01	2.90	-0.11	-2.81
5	5	1.0	10/2-10/6	3.89	15.49	10.66	3.89	0.15	0.01	2.90	-0.11	-2.81
	5.	1.0	10	4.32	14.34	15.35	7.71	0.17	-0.41	2.49	-0.32	-3.94

(Continued)

TABLE C-1-5. (CONTINUED)

6	5	1.0	10/9-10/13	4.32	14.34	15.35	2.71	0.17	-0.41	2.49	-0.32	-3.94
	0.	P	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.	1.0	24	18.16	55.59	42.07	32.58	0.21	-0.21	2.44	-0.06	-4.73
7	7	1.0	10/22-10/28	18.16	55.59	42.07	32.58	0.21	-0.21	2.44	-0.06	-4.73
	0.	P	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	NOV 7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3.	1.0	14	8.04	17.47	16.78	12.49	0.28	0.06	1.01	-0.18	-4.70
8	3	1.0	11/13-11/15	8.04	17.47	16.78	12.49	0.28	0.06	1.01	-0.18	-4.70
	0.	P	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	DEC 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.	0.4	26	8.71	29.81	10.09	9.05	0.00	-0.14	2.39	-0.01	-1.75
	7.	0.4	JAN 2	2.78	7.14	2.95	2.46	-0.11	0.02	0.56	-0.01	-1.47
	7.	0.4	9	1.37	6.82	1.41	1.13	0.17	0.07	0.23	-0.19	-1.05
	7.	0.4	16	4.04	11.66	3.95	2.22	0.12	0.09	1.17	-0.08	-2.35
	7.	0.4	23	4.28	12.55	4.52	4.08	0.07	-0.02	1.82	-0.02	-2.25
	7.	0.4	30	6.26	15.05	8.47	7.67	0.20	-0.04	1.20	-0.01	-1.39
	7.	0.4	FEB 6	9.81	20.82	9.85	9.44	0.07	-0.04	1.74	-0.00	-1.00
	6.	0.4	13	5.91	19.58	11.52	11.69	0.12	-0.00	0.58	-0.01	-0.37
9	58	0.4	12/23-2/18	43.15	123.43	52.76	42.74	0.63	-0.06	10.49	-0.34	-11.64
	0.	P	20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	8.	0.4	MAR 6	7.47	32.70	17.30	16.10	-1.31	-0.20	1.84	-0.01	-2.34
	7.	0.4	13	6.21	23.53	14.04	13.16	-0.10	-0.34	1.13	0.00	-0.47
	5.	0.4	20	5.82	19.57	14.67	12.39	0.09	-0.13	1.61	0.01	-0.12

(Continued)

TABLE C-1-5. (CONTINUED)

10	20	0.4	3/5-3/24	19.51	75.80	46.01	41.65	-1.32	-0.67	4.58	0.01	*-2.92
	0.	P	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	APR 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.	1.0	MAY 1	7.87	30.97	29.66	20.58	-0.30	-0.48	2.74	0.06	-4.90
11	7	1.0	4/29-5/5	7.87	30.97	29.66	20.58	-0.30	-0.48	2.74	0.06	-4.90
	0.	P	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.	1.0	15	8.57	31.17	17.35	12.51	-0.26	-0.76	1.60	0.02	-7.48
	5.	1.0	22	2.31	11.96	4.54	2.81	0.24	-0.15	0.57	-0.01	-0.84
12	12	1.0	5/14-5/26	10.88	43.13	21.89	15.32	-0.03	-0.91	2.16	0.02	-8.32
	0.	P	29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	JUN 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.	1.0	12	7.16	15.74	16.95	14.93	0.31	-0.19	3.26	-0.00	-5.25
13	7*	1.0	6/10-6/16	7.16	15.74	16.95	14.93	0.31	-0.19	3.26	-0.00	-5.25

* NOTE: -5.0 INDICATES MISSING DATA

TABLE C-1-6. REMOVAL DATA FOR FILTER 6

RUN	NUMBER DAYS	LOADING (MGAD)	DATE	POUNDS REMOVED								
				BOD5	COD	SS	VSS	TOTAL P	O-PO4-P	NH3-N	NO2-N	NO3-N
	6.	2.0	JUL 2	2.90	14.48	17.59	4.55	0.68	-0.44	6.51	0.17	-5.98
1	6.	2.0	7/2-7/7	2.90	14.48	17.59	4.55	0.68	-0.44	6.51	0.17	-5.98
	3.	0.2	12	0.91	5.90	-0.89	1.39	0.00	-0.01	0.22	-0.01	-1.20
	2.	0.2	15	-5.00	-5.00	0.31	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.2	17	1.29	19.04	0.06	2.84	-5.00	0.13	2.05	-0.06	-7.61
	1.	0.2	18	-5.00	-5.00	-0.37	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	1.	0.2	19	-5.00	-5.00	-0.36	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	0.2	22	-5.00	-5.00	1.68	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	3.	0.2	24	1.43	0.69	0.80	2.95	0.26	0.19	1.49	0.00	-1.59
	12.	0.2	26	-5.00	-5.00	7.81	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	-5.	0.2	31	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	-5.	0.2	AUG 6	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	7.	0.2	7	0.92	11.74	7.35	6.15	0.04	-0.13	0.25	-0.02	-0.52
	-5.	0.2	14	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	-5.	0.2	16	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00
	7.	0.2	19	-5.00	-5.00	10.81	8.58	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	0.2	21	1.60	19.35	3.35	2.17	0.19	-0.05	0.01	-0.00	-0.25
2	42	0.2	7/12-8/22	6.15	56.71	30.54	24.08	0.49	0.13	4.03	-0.09	-11.18
	2.	0.2	SEP 4	1.17	13.24	2.62	2.21	0.09	-0.07	0.01	-0.01	-1.44
	3.	0.2	6	-5.00	-5.00	3.75	2.41	-5.00	-5.00	-5.00	-5.00	-5.00
	2.	0.2	9	0.57	-5.00	1.89	1.48	-5.00	-5.00	-5.00	-5.00	-5.00
	7.	0.2	11	1.05	9.79	6.10	4.23	0.09	-0.00	0.08	-0.03	-0.48
	2.	0.2	18	0.31	4.26	0.70	0.48	0.11	0.05	0.19	-0.04	-0.70
	6.	0.2	20	1.28	-5.00	2.12	1.37	-5.00	-5.00	-5.00	-5.00	-5.00
	7.	0.2	26	0.65	1.89	4.44	2.33	0.14	0.15	0.46	-0.00	-0.97
	7.	0.2	OCT 3	0.88	4.51	3.14	1.17	0.14	0.09	0.56	0.00	-1.23
	7.	0.2	10	1.40	4.97	4.27	2.26	0.15	-0.08	0.79	-0.00	-1.25
	7.	0.2	17	1.97	5.26	5.57	1.80	0.02	-0.05	0.38	0.00	-1.20
	7.	0.2	24	3.88	11.78	8.78	6.91	0.22	-0.03	0.52	0.01	-1.12
	6.	0.2	31	3.70	6.41	5.57	4.47	0.06	-0.03	0.42	0.00	-0.89
	7.	0.2	NOV 7	2.35	3.88	5.13	3.71	0.15	-0.01	1.29	-0.01	-0.89
	7.	0.2	14	4.04	8.78	8.13	6.06	0.07	-0.05	0.53	-0.00	-1.04
	5.	0.2	21	1.09	3.98	3.19	1.69	-0.02	-0.04	0.73	-0.08	-0.73
	9.	0.2	26	3.42	7.41	8.32	4.80	-0.15	-0.09	1.04	0.00	-0.76
	7.	0.2	DEC 5	3.86	6.98	4.55	3.67	0.02	-0.06	0.65	-0.04	-1.43
	7.	0.2	12	4.36	8.72	6.10	5.43	0.09	-0.01	0.59	-0.01	-0.76

(Continued)

TABLE C-1-6. (CONTINUED)

	7.	0.2	15	1.80	4.51	2.77	2.28	0.02	-0.03	0.75	-0.00	-0.68
	7.	0.2	26	3.21	11.78	3.71	3.31	0.07	0.01	1.12	-0.00	-0.78
	7.	0.2	JAN 2	1.51	4.63	1.57	1.24	0.02	0.00	0.65	-0.00	-0.81
	7.	0.2	9	0.78	4.13	0.88	0.63	0.08	0.03	0.13	0.00	-1.52
	7.	0.2	16	1.93	5.78	2.18	1.15	0.06	0.03	0.65	0.00	-0.18
	7.	0.2	23	1.68	5.85	2.28	1.99	0.05	0.04	1.06	-0.00	-0.28
	7.	0.2	30	3.31	9.79	4.55	4.04	0.10	0.04	0.51	-0.00	-0.26
	7.	0.2	FEB 6	5.07	10.20	5.26	5.05	0.14	0.03	0.80	-0.00	-0.34
	7.	0.2	13	3.92	13.52	7.31	7.44	0.16	0.07	0.47	-0.01	-0.40
	7.	0.2	20	3.60	10.33	7.33	7.17	0.23	-0.00	0.54	-0.00	-0.35
	7.	0.2	27	4.15	12.43	6.50	6.56	0.01	-0.03	0.46	0.00	-0.58
	6.	0.2	MAR 6	2.26	12.95	7.09	6.56	-0.36	-0.02	0.45	0.00	-0.11
3	188	0.2	9/4-3/11	69.18	207.72	135.82	103.89	1.73	-0.06	16.24	-0.21	-21.18
	0.	P	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.	P	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.	0.2	APR 3	5.06	17.81	12.20	9.91	0.22	0.05	0.34	0.00	-1.52
	7.	0.2	10	2.89	10.88	5.20	3.65	0.13	0.02	0.50	0.01	-0.80
	5.	0.2	17	1.45	6.90	3.01	1.57	0.05	-0.00	0.57	0.01	-1.04
	7.	0.2	24	5.01	9.05	5.03	2.45	0.04	-0.02	0.54	0.01	-1.21
	7.	0.2	MAY 1	1.93	10.10	6.62	4.57	-0.01	-0.04	0.57	0.01	-1.17
	7.	0.2	8	2.68	11.23	8.88	5.68	0.06	-0.07	0.40	0.02	-0.77
	6.	0.2	15	1.72	6.57	3.20	2.42	0.00	-0.08	0.31	0.01	-1.52
	7.	0.2	22	0.94	5.64	1.19	0.86	-0.02	-0.13	0.20	0.02	-0.69
	7.	0.2	29	10.00	25.98	17.90	14.23	0.26	-0.03	0.38	0.01	-1.11
	7.	0.2	JUN 5	60.18	90.21	26.70	22.76	0.51	-0.07	0.47	0.01	-1.35
	7.	0.2	12	1.63	5.11	3.42	3.14	0.08	-0.05	0.67	-0.00	-1.48
	7.	0.2	19	1.28	8.07	1.93	1.09	0.07	-0.13	0.49	0.00	-1.74
	2.	0.2	26	0.56	3.35	1.20	0.98	-0.02	-0.02	0.27	0.00	-0.39
4	85*	0.2	4/1-6/27	95.34	210.50	96.47	73.31	1.37	-0.58	6.11	0.11	-14.78

* NOTE: -5.0 INDICATES MISSING DATA

TABLE C-2-1. FILTER COMPARISON FOR POUNDS OF BIOCHEMICAL OXYGEN DEMAND REMOVED OVER EACH RUN

RUN COMPARISON SUMMARY FOR BODS

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
1	15.27 LBS 33 DAYS 7/2-8/7 0.4 MGAD	17.67 LBS 31 DAYS 7/2-8/5 0.6 MGAD	14.79 LBS 28 DAYS 7/2-7/31 0.8 MGAD	12.04 LBS 26 DAYS 7/2-7/29 1.0 MGAD	7.66 LBS 21 DAYS 7/2-7/24 1.2 MGAD	2.90 LBS 6+ DAYS 7/2-7/7 2.0 MGAD
2	9.53 LBS 25 DAYS 9/4-9/28 0.4 MGAD	5.78 LBS 8 DAYS 8/14-8/22 0.6 MGAD	8.75 LBS 6 DAYS 8/14-8/20 0.8 MGAD	4.87 LBS 3 DAYS 8/14-8/16 1.0 MGAD	5.44 LBS 3 DAYS 8/14-8/16 1.2 MGAD	6.15 LBS 42 DAYS 7/12-8/22 0.2 MGAD
3	20.59 LBS 31 DAYS 10/2-11/3 0.4 MGAD	7.93 LBS 12 DAYS 9/4-9/15 0.6 MGAD	9.09 LBS 9 DAYS 9/4-9/12 0.8 MGAD	4.66 LBS 4 DAYS 9/4-9/7 1.0 MGAD	8.98 LBS 9 DAYS 9/4-9/12 1.0 MGAD	65.18 LBS 188 DAYS 9/4-3/11 0.2 MGAD
4	119.82 LBS 130 DAYS 11/13-3/22 0.4 MGAD	14.44 LBS 27 DAYS 9/26-10/22 0.6 MGAD	13.04 LBS 19 DAYS 9/18-10/6 0.8 MGAD	5.41 LBS 10 DAYS 9/18-9/27 1.0 MGAD	8.45 LBS 10 DAYS 9/18-9/27 1.0 MGAD	95.34 LBS 85+ DAYS 4/1-6/27 0.2 MGAD
5	26.38 LBS 34 DAYS 4/5-5/10 0.4 MGAD	23.54 LBS 16 DAYS 10/31-11/16 0.6 MGAD	11.38 LBS 13 DAYS 10/9-10/21 0.8 MGAD	4.43 LBS 5 DAYS 10/2-10/6 1.0 MGAD	3.89 LBS 5 DAYS 10/2-10/6 1.0 MGAD	
6	163.92 LBS 40+ DAYS 5/17-6/27 0.4 MGAD	13.16 LBS 14 DAYS 11/20-12/4 0.6 MGAD		5.33 LBS 5 DAYS 10/9-10/13 1.0 MGAD	4.32 LBS 5 DAYS 10/9-10/13 1.0 MGAD	
7		37.35 LBS 73 DAYS 1/1-3/21 0.4 MGAD		17.81 LBS 6 DAYS 10/23-10/28 1.0 MGAD	18.16 LBS 7 DAYS 10/22-10/28 1.0 MGAD	
8		15.42 LBS 13 DAYS 4/15-4/29 0.6 MGAD		24.53 LBS 8 DAYS 11/13-11/20 1.0 MGAD	8.04 LBS 3 DAYS 11/13-11/15 1.0 MGAD	

(Continued)

TABLE C-2-1. (CONTINUED)

9	150.31 LBS 25 DAYS 5/14-6/8 0.6 MGAC	130.19 LBS 141- DAYS 12/23-5/14 0.4 MGAC	43.15 LBS 58 DAYS 12/23-2/18 0.4 MGAC
10			19.51 LBS 20 DAYS 3/5-3/24 0.4 MGAC
11			7.87 LBS 7 DAYS 4/29-5/5 1.0 MGAC
12			10.88 LBS 12 DAYS 5/14-5/26 1.0 MGAC
13			7.16 LBS 7+ DAYS 6/10-6/16 1.0 MGAC

TABLE C-2-2. FILTER COMPARISON FOR POUNDS OF CHEMICAL OXYGEN DEMAND REMOVED OVER EACH RUN

RUN COMPARISON SUMMARY FOR COD

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
1	117.54 LBS 33 DAYS 7/2-8/7 0.4 MGAD	126.39 LBS 31 DAYS 7/2-8/5 0.6 MGAD	94.31 LBS 28 DAYS 7/2-7/31 0.8 MGAD	141.82 LBS 26 DAYS 7/2-7/29 1.0 MGAD	79.26 LBS 21 DAYS 7/2-7/24 1.2 MGAD	14.48 LBS 6+ DAYS 7/2-7/7 2.0 MGAD
2	63.13 LBS 25 DAYS 9/4-9/28 0.4 MGAD	45.48 LBS 8 DAYS 8/14-8/22 0.6 MGAD	50.35 LBS 6 DAYS 8/14-8/20 0.8 MGAD	25.45 LBS 3 DAYS 8/14-8/16 1.0 MGAD	28.90 LBS 3 DAYS 8/14-8/16 1.2 MGAD	56.71 LBS 42 DAYS 7/12-8/22 0.2 MGAD
3	58.52 LBS 31 DAYS 10/2-11/3 0.4 MGAD	65.62 LBS 12 DAYS 9/4-9/15 0.6 MGAD	73.08 LBS 9 DAYS 9/4-9/12 0.8 MGAD	40.74 LBS 4 DAYS 9/4-9/7 1.0 MGAD	78.49 LBS 9 DAYS 9/4-9/12 1.0 MGAD	207.72 LBS 188 DAYS 9/4-3/11 0.2 MGAD
4	346.69 LBS 130 DAYS 11/13-3/22 0.4 MGAD	47.38 LBS 27 DAYS 9/26-10/22 0.6 MGAD	37.47 LBS 15 DAYS 9/18-10/6 0.8 MGAD	17.38 LBS 10 DAYS 9/18-9/27 1.0 MGAD	14.82 LBS 10 DAYS 9/18-9/27 1.0 MGAD	210.50 LBS 85+ DAYS 4/1-6/27 0.2 MGAD
5	83.20 LBS 34 DAYS 4/5-5/10 0.4 MGAD	48.50 LBS 16 DAYS 10/31-11/16 0.6 MGAD	41.75 LBS 13 DAYS 10/9-10/21 0.8 MGAD	14.92 LBS 5 DAYS 10/2-10/6 1.0 MGAD	15.49 LBS 5 DAYS 10/2-10/6 1.0 MGAD	
6	306.08 LBS 40+ DAYS 5/17-6/22 0.4 MGAD	30.44 LBS 14 DAYS 11/20-12/4 0.6 MGAD		15.83 LBS 5 DAYS 10/9-10/13 1.0 MGAD	14.34 LBS 5 DAYS 10/9-10/13 1.0 MGAD	
7		134.77 LBS 73 DAYS 1/1-3/21 0.4 MGAD		50.18 LBS 6 DAYS 10/23-10/28 1.0 MGAD	55.99 LBS 7 DAYS 10/22-10/28 1.0 MGAD	
8		45.68 LBS 13 DAYS 4/15-4/29 0.6 MGAD		49.99 LBS 8 DAYS 11/13-11/20 1.0 MGAD	17.47 LBS 3 DAYS 11/13-11/15 1.0 MGAD	

(Continued)

TABLE C-2-2. (CONTINUED)

9	281.45 LBS 25 DAYS 5/14-6/8 0.6 MGAC	421.C9 LBS 141- CAYS 12/23-5/14 0.4 MGAD	123.43 LBS 58 DAYS 12/23-2/18 0.4 MGAC
10			75.80 LBS 20 DAYS 3/5-3/24 0.4 MGAC
11			30.97 LBS 7 DAYS 4/29-5/5 1.0 MGAC
12			43.13 LBS 12 DAYS 5/14-5/26 1.0 MGAC
13			15.74 LBS 7+ DAYS 6/10-6/16 1.0 MGAC

TABLE C-2-3. FILTER COMPARISON FOR POUNDS OF SUSPENDED SOLIDS REMOVED OVER EACH RUN

RUN COMPARISON SUMMARY FOR SS

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
1	27.97 LBS 33 DAYS 7/2-8/7 0.4 MGAD	24.86 LBS 31 DAYS 7/2-8/5 0.6 MGAD	36.09 LBS 28 DAYS 7/2-7/31 0.8 MGAD	34.89 LBS 26 DAYS 7/2-7/29 1.0 MGAD	27.03 LBS 21 DAYS 7/2-7/24 1.2 MGAD	17.59 LBS 6+ DAYS 7/2-7/7 2.0 MGAD
2	41.16 LBS 25 DAYS 9/4-9/28 0.4 MGAD	37.85 LBS 8 DAYS 8/14-8/22 0.6 MGAD	39.52 LBS 6 DAYS 8/14-8/20 0.8 MGAD	20.74 LBS 3 DAYS 8/14-8/16 1.0 MGAD	23.09 LBS 3 DAYS 8/14-8/16 1.2 MGAD	30.54 LBS 42 DAYS 7/12-8/22 0.2 MGAD
3	53.33 LBS 31 DAYS 10/2-11/3 0.4 MGAD	38.54 LBS 12 DAYS 9/4-9/15 0.6 MGAD	42.43 LBS 9 DAYS 9/4-9/12 0.8 MGAD	24.70 LBS 4 DAYS 9/4-9/7 1.0 MGAD	46.23 LBS 9 DAYS 9/4-9/12 1.0 MGAD	135.62 LBS 188 DAYS 9/4-3/11 0.2 MGAD
4	211.63 LBS 130 DAYS 11/13-3/22 0.4 MGAD	49.11 LBS 27 DAYS 9/26-10/22 0.6 MGAD	40.06 LBS 19 DAYS 9/18-10/6 0.8 MGAD	12.96 LBS 10 DAYS 9/18-9/27 1.0 MGAD	17.81 LBS 10 DAYS 9/18-9/27 1.0 MGAD	96.47 LBS 85+ DAYS 4/1-6/27 0.2 MGAD
5	60.33 LBS 34 DAYS 4/5-5/10 0.4 MGAD	49.97 LBS 16 DAYS 10/31-11/16 0.6 MGAD	41.75 LBS 13 DAYS 10/9-10/21 0.8 MGAD	11.64 LBS 5 DAYS 10/2-10/6 1.0 MGAD	10.66 LBS 5 DAYS 10/2-10/6 1.0 MGAD	
6	120.35 LBS 40+ DAYS 5/17-6/27 0.4 MGAD	35.39 LBS 14 DAYS 11/20-12/4 0.6 MGAD		17.30 LBS 5 DAYS 10/9-10/13 1.0 MGAD	15.35 LBS 5 DAYS 10/9-10/13 1.0 MGAD	
7		80.87 LBS 73 DAYS 1/1-3/21 0.4 MGAD		40.44 LBS 6 DAYS 10/23-10/28 1.0 MGAD	42.07 LBS 7 DAYS 10/22-10/28 1.0 MGAD	
8		25.46 LBS 13 DAYS 4/15-4/29 0.6 MGAD		50.38 LBS 8 DAYS 11/13-11/20 1.0 MGAD	16.78 LBS 3 DAYS 11/13-11/15 1.0 MGAD	

(Continued)

TABLE C-2-3. (CONTINUED)

9	123.81 LBS 25 DAYS 5/14-6/8 0.6 MGAC	241.53 LBS 141- DAYS 12/23-5/14 0.4 MGAD	52.76 LBS 58 DAYS 12/23-2/18 0.4 MGAC
10			46.01 LBS 20 DAYS 3/5-3/24 0.4 MGAC
11			29.66 LBS 7 DAYS 4/29-5/5 1.0 MGAC
12			21.89 LBS 12 DAYS 5/14-5/26 1.0 MGAC
13			16.95 LBS 7+ DAYS 6/10-6/16 1.0 MGAC

TABLE C-2-4. FILTER COMPARISON FOR POUNDS OF VOLATILE SUSPENDED SOLIDS REMOVED OVER EACH RUN

RUN COMPARISON SUMMARY FOR VSS

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
1	17.83 LBS 33 DAYS 7/2-8/2 0.4 MGAD	19.90 LBS 31 DAYS 7/2-8/5 0.6 MGAD	22.74 LBS 26 DAYS 7/2-7/31 0.8 MGAD	23.22 LBS 26 DAYS 7/2-7/29 1.0 MGAD	21.21 LBS 21 DAYS 7/2-7/24 1.2 MGAD	4.55 LBS 6+ DAYS 7/2-7/7 2.0 MGAD
2	28.57 LBS 25 DAYS 9/4-9/28 0.4 MGAD	27.90 LBS 8 DAYS 8/14-8/22 0.6 MGAD	32.60 LBS 6 DAYS 8/14-8/20 0.8 MGAD	19.97 LBS 3 DAYS 8/14-8/16 1.0 MGAD	20.74 LBS 3 DAYS 8/14-8/16 1.2 MGAD	24.08 LBS 42 DAYS 7/12-8/22 0.2 MGAD
3	30.04 LBS 31 DAYS 10/2-11/3 0.4 MGAD	29.17 LBS 12 DAYS 9/4-9/15 0.6 MGAD	31.66 LBS 9 DAYS 9/4-9/12 0.8 MGAD	19.09 LBS 4 DAYS 9/4-9/7 1.0 MGAD	34.42 LBS 9 DAYS 9/4-9/12 1.0 MGAD	103.89 LBS 188 DAYS 9/4-3/11 0.2 MGAD
4	177.49 LBS 130 DAYS 11/13-3/22 0.4 MGAD	23.21 LBS 27 DAYS 9/26-10/22 0.6 MGAD	22.05 LBS 15 DAYS 9/18-10/6 0.8 MGAD	11.35 LBS 10 DAYS 9/18-9/27 1.0 MGAD	11.53 LBS 10 DAYS 9/18-9/27 1.0 MGAD	73.31 LBS 85+ DAYS 4/1-6/27 0.2 MGAD
5	36.92 LBS 34 DAYS 4/5-5/10 0.4 MGAD	36.49 LBS 16 DAYS 10/31-11/16 0.6 MGAD	17.46 LBS 13 DAYS 10/9-10/21 0.8 MGAD	4.51 LBS 5 DAYS 10/2-10/6 1.0 MGAD	3.89 LBS 5 DAYS 10/2-10/6 1.0 MGAD	
6	95.31 LBS 40+ DAYS 5/17-6/27 0.4 MGAD	19.34 LBS 14 DAYS 11/20-12/4 0.6 MGAD		8.61 LBS 5 DAYS 10/9-10/13 1.0 MGAD	7.71 LBS 5 DAYS 10/9-10/13 1.0 MGAD	
7		79.56 LBS 73 DAYS 1/1-3/21 0.4 MGAD		31.88 LBS 6 DAYS 10/23-10/28 1.0 MGAD	32.58 LBS 7 DAYS 10/22-10/28 1.0 MGAD	
8		12.46 LBS 13 DAYS 4/15-4/29 0.6 MGAD		37.78 LBS 8 DAYS 11/13-11/20 1.0 MGAD	12.49 LBS 3 DAYS 11/13-11/15 1.0 MGAD	

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TABLE C-2-4. (CONTINUED)

9	99.80 LBS 25 DAYS 5/14-6/8 0.6 MGAC	201.22 LBS 141- DAYS 12/23-5/14 0.4 MGAC	47.74 LBS 58 DAYS 12/23-2/18 0.4 MGAC
10			41.65 LBS 20 DAYS 3/5-3/24 0.4 MGAC
11			20.58 LBS 7 DAYS 4/29-5/5 1.0 MGAC
12			15.32 LBS 12 DAYS 5/14-5/26 1.0 MGAC
13			14.93 LBS 7+ DAYS 6/10-6/16 1.0 MGAC

TABLE C-2-5. FILTER COMPARISON FOR POUNDS OF TOTAL SOLUBLE PHOSPHORUS REMOVED OVER EACH RUN

RUN COMPARISON SUMMARY FOR TOTAL P

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
1	2.13 LBS 33 DAYS 7/2-8/7 0.4 MGAD	0.61 LBS 31 DAYS 7/2-8/5 0.6 MGAD	1.47 LBS 28 DAYS 7/2-7/31 0.8 MGAD	1.47 LBS 26 DAYS 7/2-7/29 1.0 MGAD	0.92 LBS 21 DAYS 7/2-7/24 1.2 MGAD	0.68 LBS 6+ DAYS 7/2-7/7 2.0 MGAD
2	1.04 LBS 25 DAYS 9/4-9/28 0.4 MGAD	0.55 LBS 8 DAYS 8/14-8/22 0.6 MGAD	0.29 LBS 6 DAYS 8/14-8/20 0.8 MGAD	0.20 LBS 3 DAYS 8/14-8/16 1.0 MGAD	0.21 LBS 3 DAYS 8/14-8/16 1.2 MGAD	0.49 LBS 42 DAYS 7/12-8/22 0.2 MGAD
3	0.93 LBS 31 DAYS 10/2-11/3 0.4 MGAD	0.68 LBS 12 DAYS 9/4-9/15 0.6 MGAD	0.94 LBS 9 DAYS 9/4-9/12 0.8 MGAD	0.43 LBS 4 DAYS 9/4-9/7 1.0 MGAD	0.77 LBS 9 DAYS 9/4-9/12 1.0 MGAD	1.73 LBS 188 DAYS 9/4-3/11 0.2 MGAD
4	1.59 LBS 130 DAYS 11/13-3/22 0.4 MGAD	1.47 LBS 27 DAYS 9/26-10/22 0.6 MGAD	1.61 LBS 19 DAYS 9/18-10/6 0.8 MGAD	0.85 LBS 10 DAYS 9/18-9/27 1.0 MGAD	0.56 LBS 10 DAYS 9/18-9/27 1.0 MGAD	1.37 LBS 85+ DAYS 4/1-6/27 0.2 MGAD
5	1.26 LBS 34 DAYS 4/5-5/10 0.4 MGAD	0.77 LBS 16 DAYS 10/31-11/16 0.6 MGAD	0.44 LBS 13 DAYS 10/9-10/21 0.8 MGAD	0.16 LBS 5 DAYS 10/2-10/6 1.0 MGAD	0.15 LBS 5 DAYS 10/2-10/6 1.0 MGAD	
6	2.75 LBS 40+ DAYS 5/17-6/27 0.4 MGAD	0.03 LBS 14 DAYS 11/20-12/4 0.6 MGAD		0.29 LBS 5 DAYS 10/9-10/13 1.0 MGAD	0.17 LBS 5 DAYS 10/9-10/13 1.0 MGAD	
7		0.96 LBS 73 DAYS 1/1-3/21 0.4 MGAD		0.28 LBS 6 DAYS 10/23-10/28 1.0 MGAD	0.21 LBS 7 DAYS 10/22-10/28 1.0 MGAD	
8		1.26 LBS 13 DAYS 4/15-4/29 0.6 MGAD		0.78 LBS 8 DAYS 11/13-11/20 1.0 MGAD	0.28 LBS 3 DAYS 11/13-11/15 1.0 MGAD	

(Continued)

TABLE C-2-5. (CONTINUED)

9	2.22 LBS 25 DAYS 5/14-6/8 0.6 MGAD	1.13 LBS 141- DAYS 12/23-5/14 0.4 MGAD	0.63 LBS 58 DAYS 12/23-2/18 0.4 MGAD
10			-1.32 LBS 20 DAYS 3/5-3/24 0.4 MGAD
11			-0.30 LBS 7 DAYS 4/29-5/5 1.0 MGAD
12			-0.03 LBS 12 DAYS 5/14-5/26 1.0 MGAD
13			0.31 LBS 7+ DAYS 6/10-6/16 1.0 MGAD

TABLE C-2-6. FILTER COMPARISON FOR POUNDS OF ORTHOPHOSPHATE AS PHOSPHORUS REMOVED OVER EACH RUN

RUN COMPARISON SUMMARY FOR 0-FC4-F

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
1	1.84 LBS 33 DAYS 7/2-8/7 0.4 MGAD	1.36 LBS 31 DAYS 7/2-8/5 0.6 MGAD	1.01 LBS 28 DAYS 7/2-7/31 0.8 MGAD	0.93 LBS 26 DAYS 7/2-7/29 1.0 MGAD	0.50 LBS 21 DAYS 7/2-7/24 1.2 MGAD	-0.44 LBS 6+ DAYS 7/2-7/7 2.0 MGAD
2	0.31 LBS 25 DAYS 9/4-9/28 0.4 MGAD	-0.01 LBS 8 DAYS 8/14-8/22 0.6 MGAD	-0.24 LBS 6 DAYS 8/14-8/20 0.8 MGAD	-0.12 LBS 3 DAYS 8/14-8/16 1.0 MGAD	-0.13 LBS 3 DAYS 8/14-8/16 1.2 MGAD	0.13 LBS 42 DAYS 7/12-8/22 0.2 MGAD
3	-0.02 LBS 31 DAYS 10/2-11/3 0.4 MGAD	0.12 LBS 12 DAYS 9/4-9/15 0.6 MGAD	-0.08 LBS 9 DAYS 9/4-9/12 0.8 MGAD	-0.06 LBS 4 DAYS 9/4-9/7 1.0 MGAD	0.13 LBS 9 DAYS 9/4-9/12 1.0 MGAD	-0.06 LBS 188 DAYS 9/4-3/11 0.2 MGAD
4	-0.47 LBS 130 DAYS 11/13-3/22 0.4 MGAD	0.72 LBS 27 DAYS 9/26-10/22 0.6 MGAD	0.99 LBS 19 DAYS 9/18-10/6 0.8 MGAD	0.23 LBS 10 DAYS 9/18-9/27 1.0 MGAD	0.14 LBS 10 DAYS 9/18-9/27 1.0 MGAD	-0.58 LBS 85+ DAYS 4/1-6/27 0.2 MGAD
5	0.29 LBS 34 DAYS 4/5-5/10 0.4 MGAD	-0.14 LBS 16 DAYS 10/31-11/16 0.6 MGAD	-0.66 LBS 13 DAYS 10/5-10/21 0.8 MGAD	0.07 LBS 5 DAYS 10/2-10/6 1.0 MGAD	0.01 LBS 5 DAYS 10/2-10/6 1.0 MGAD	
6	0.08 LBS 40+ DAYS 5/17-6/27 0.4 MGAD	-0.13 LBS 14 DAYS 11/20-12/4 0.6 MGAD		-0.42 LBS 5 DAYS 10/9-10/13 1.0 MGAD	-0.41 LBS 5 DAYS 10/9-10/13 1.0 MGAD	
7		0.30 LBS 73 DAYS 1/1-3/21 0.4 MGAD		-0.17 LBS 6 DAYS 10/23-10/28 1.0 MGAD	-0.21 LBS 7 DAYS 10/22-10/28 1.0 MGAD	
8		1.02 LBS 13 DAYS 4/15-4/29 0.6 MGAD		0.06 LBS 8 DAYS 11/13-11/20 1.0 MGAD	0.06 LBS 3 DAYS 11/13-11/15 1.0 MGAD	

(Continued)

TABLE C-2-6. (CONTINUED)

9	-0.52 LBS 25 DAYS 5/14-6/8 0.6 MGAC	-1.87 LBS 141- DAYS 12/23-5/14 0.4 MGAC	-0.06 LBS 58 DAYS 12/23-2/18 0.4 MGAC
10			-0.67 LBS 20 DAYS 3/5-3/24 0.4 MGAC
11			-0.48 LBS 7 DAYS 4/29-5/5 1.0 MGAC
12			-0.91 LBS 12 DAYS 5/14-5/26 1.0 MGAC
13			-0.19 LBS 7+ DAYS 6/10-6/16 1.0 MGAC

TABLE C-2-7. FILTER COMPARISON FOR POUNDS OF AMMONIA AS NITROGEN REMOVED OVER EACH RUN

RUN COMPARISON SUMMARY FOR NH3-N

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
1	6.28 LBS 33 DAYS 7/2-8/7 0.4 MGAD	8.42 LBS 31 DAYS 7/2-8/5 0.6 MGAD	11.36 LBS 28 DAYS 7/2-7/31 0.8 MGAD	11.42 LBS 26 DAYS 7/2-7/29 1.0 MGAD	9.40 LBS 21 DAYS 7/2-7/24 1.2 MGAD	6.51 LBS 6+ DAYS 7/2-7/7 2.0 MGAD
2	0.88 LBS 25 DAYS 9/4-9/28 0.4 MGAD	0.00 LBS 8 DAYS 8/14-8/22 0.6 MGAD	0.07 LBS 6 DAYS 8/14-8/20 0.8 MGAD	0.05 LBS 3 DAYS 8/14-8/16 1.0 MGAD	0.02 LBS 3 DAYS 8/14-8/16 1.2 MGAD	4.03 LBS 42 DAYS 7/12-8/22 0.2 MGAD
3	5.78 LBS 31 DAYS 10/2-11/3 0.4 MGAD	0.16 LBS 12 DAYS 9/4-9/15 0.6 MGAD	0.15 LBS 9 DAYS 9/4-9/12 0.8 MGAD	0.02 LBS 4 DAYS 9/4-9/7 1.0 MGAD	0.05 LBS 9 DAYS 9/4-9/12 1.0 MGAD	16.24 LBS 188 DAYS 9/4-3/11 0.2 MGAD
4	32.30 LBS 130 DAYS 11/13-3/22 0.4 MGAD	7.18 LBS 27 DAYS 9/26-10/22 0.6 MGAD	5.27 LBS 19 DAYS 9/18-10/6 0.8 MGAD	2.84 LBS 10 DAYS 9/18-9/27 1.0 MGAD	1.48 LBS 10 DAYS 9/18-9/27 1.0 MGAD	6.11 LBS 85+ DAYS 4/1-6/27 0.2 MGAD
5	5.80 LBS 34 DAYS 4/5-5/10 0.4 MGAD	4.15 LBS 16 DAYS 10/31-11/16 0.6 MGAD	5.01 LBS 13 DAYS 10/9-10/21 0.8 MGAD	3.64 LBS 5 DAYS 10/2-10/6 1.0 MGAD	2.90 LBS 5 DAYS 10/2-10/6 1.0 MGAD	
6	5.12 LBS 40+ DAYS 5/17-6/27 0.4 MGAD	5.15 LBS 14 DAYS 11/20-12/4 0.6 MGAD		2.89 LBS 5 DAYS 10/9-10/13 1.0 MGAD	2.49 LBS 5 DAYS 10/9-10/13 1.0 MGAD	
7		2.06 LBS 73 DAYS 1/1-3/21 0.4 MGAD		2.39 LBS 6 DAYS 10/23-10/28 1.0 MGAD	2.44 LBS 7 DAYS 10/22-10/28 1.0 MGAD	
8		4.44 LBS 13 DAYS 4/15-4/29 0.6 MGAD		3.19 LBS 8 DAYS 11/13-11/20 1.0 MGAD	1.01 LBS 3 DAYS 11/13-11/15 1.0 MGAD	

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TABLE C-2-7. (CONTINUED)

9	3.21 LBS 25 DAYS 5/14-6/8 0.6 MGAC	29.55 LBS 141- DAYS 12/23-5/14 0.4 MGAC	10.49 LBS 58 DAYS 12/23-2/16 0.4 MGAC
10			4.58 LBS 20 DAYS 3/5-3/24 0.4 MGAC
11			2.74 LBS 7 DAYS 4/29-5/5 1.0 MGAC
12			2.16 LBS 12 DAYS 5/14-5/26 1.0 MGAC
13			3.26 LBS 7+ DAYS 6/10-6/16 1.0 MGAC

TABLE C-2-8. FILTER COMPARISON FOR POUNDS OF NITRITE AS NITROGEN REMOVED OVER EACH RUN

RUN COMPARISON SUMMARY FOR NO2-N

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
1	-0.44 LBS 33 DAYS 7/2-8/7 0.4 MGAD	-0.70 LBS 31 DAYS 7/2-8/5 0.6 MGAD	-1.03 LBS 28 DAYS 7/2-7/31 0.8 MGAD	-1.34 LBS 26 DAYS 7/2-7/29 1.0 MGAD	-1.65 LBS 21 DAYS 7/2-7/24 1.2 MGAD	0.17 LBS 6+ DAYS 7/2-7/7 2.0 MGAD
2	-0.20 LBS 25 DAYS 9/4-9/28 0.4 MGAD	-0.01 LBS 8 DAYS 8/14-8/22 0.6 MGAD	-0.00 LBS 6 DAYS 8/14-8/20 0.8 MGAD	0.00 LBS 3 DAYS 8/14-8/16 1.0 MGAD	-0.01 LBS 3 DAYS 8/14-8/16 1.2 MGAD	-0.09 LBS 42 DAYS 7/12-8/22 0.2 MGAD
3	-0.11 LBS 31 DAYS 10/2-11/3 0.4 MGAD	-0.04 LBS 12 DAYS 9/4-9/15 0.6 MGAD	-0.04 LBS 9 DAYS 9/4-9/12 0.8 MGAD	-0.02 LBS 4 DAYS 9/4-9/7 1.0 MGAD	-0.13 LBS 9 DAYS 9/4-9/12 1.0 MGAD	-0.21 LBS 188 DAYS 9/4-3/11 0.2 MGAD
4	-0.24 LBS 130 DAYS 11/13-3/22 0.4 MGAD	-0.20 LBS 27 DAYS 9/26-10/22 0.6 MGAD	-0.22 LBS 19 DAYS 9/18-10/6 0.8 MGAD	-0.21 LBS 10 DAYS 9/18-9/27 1.0 MGAD	-0.19 LBS 10 DAYS 9/18-9/27 1.0 MGAD	0.11 LBS 85+ DAYS 4/1-6/27 0.2 MGAD
5	0.02 LBS 34 DAYS 4/5-5/10 0.4 MGAD	-0.26 LBS 16 DAYS 10/31-11/16 0.6 MGAD	-0.10 LBS 13 DAYS 10/9-10/21 0.8 MGAD	-0.06 LBS 5 DAYS 10/2-10/6 1.0 MGAD	-0.11 LBS 5 DAYS 10/2-10/6 1.0 MGAD	
6	-0.05 LBS 40+ DAYS 5/17-6/27 0.4 MGAD	-0.29 LBS 14 DAYS 11/20-12/4 0.6 MGAD		-0.13 LBS 5 DAYS 10/9-10/13 1.0 MGAD	-0.32 LBS 5 DAYS 10/9-10/13 1.0 MGAD	
7		-0.11 LBS 73 DAYS 1/1-3/21 0.4 MGAD		-0.01 LBS 6 DAYS 10/23-10/28 1.0 MGAD	-0.06 LBS 7 DAYS 10/22-10/28 1.0 MGAD	
8		-0.15 LBS 13 DAYS 4/15-4/29 0.6 MGAD		-0.23 LBS 8 DAYS 11/13-11/20 1.0 MGAD	-0.18 LBS 3 DAYS 11/13-11/15 1.0 MGAD	

(Continued)

TABLE C-2-8. (CONTINUED)

9	0.04 LBS 25 DAYS 5/14-6/8 0.6 MGAD	-0.61 LBS 141- DAYS 12/23-5/14 0.4 MGAD	-0.34 LBS 58 DAYS 12/23-2/18 0.4 MGAD
10			0.01 LBS 20 DAYS 3/5-3/24 0.4 MGAD
11			0.06 LBS 7 DAYS 4/29-5/5 1.0 MGAD
12			0.02 LBS 12 DAYS 5/14-5/26 1.0 MGAD
13			-0.00 LBS 7+ DAYS 6/10-6/16 1.0 MGAD

TABLE C-2-9. FILTER COMPARISON FOR POUNDS OF NITRATE AS NITROGEN REMOVED OVER EACH RUN

RUN COMPARISON SUMMARY FOR NO3-N

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
1	-8.77 LBS 33 DAYS 7/2-8/7 0.4 MGAD	-16.66 LBS 31 DAYS 7/2-8/5 0.6 MGAD	-14.63 LBS 28 DAYS 7/2-7/31 0.8 MGAD	-12.75 LBS 26 DAYS 7/2-7/29 1.0 MGAD	-8.79 LBS 21 DAYS 7/2-7/24 1.2 MGAD	-5.58 LBS 6+ DAYS 7/2-7/7 2.0 MGAD
2	-4.16 LBS 25 DAYS 9/4-9/28 0.4 MGAD	-0.65 LBS 8 DAYS 8/14-8/22 0.6 MGAD	-1.84 LBS 6 DAYS 8/14-8/20 0.8 MGAD	-0.52 LBS 3 DAYS 8/14-8/16 1.0 MGAD	-0.72 LBS 3 DAYS 8/14-8/16 1.2 MGAD	-11.18 LBS 42 DAYS 7/12-8/22 0.2 MGAD
3	-8.64 LBS 31 DAYS 10/2-11/3 0.4 MGAD	-3.61 LBS 12 DAYS 9/4-9/15 0.6 MGAD	-1.41 LBS 5 DAYS 9/4-9/12 0.8 MGAG	-1.67 LBS 4 DAYS 9/4-9/7 1.0 MGAD	-5.70 LBS 9 DAYS 9/4-9/12 1.0 MGAD	-21.18 LBS 188 DAYS 9/4-3/11 0.2 MGAD
4	-44.39 LBS 130 DAYS 11/13-3/22 0.4 MGAD	-11.01 LBS 27 DAYS 9/26-10/22 0.6 MGAD	-6.78 LBS 19 DAYS 9/18-10/6 0.8 MGAD	-4.00 LBS 10 DAYS 9/18-9/27 1.0 MGAD	-4.07 LBS 10 DAYS 9/18-9/27 1.0 MGAD	-14.78 LBS 85+ DAYS 4/1-6/27 0.2 MGAD
5	-2.29 LBS 34 DAYS 4/5-5/10 0.4 MGAD	-5.52 LBS 16 DAYS 10/31-11/16 0.6 MGAD	-10.08 LBS 13 DAYS 10/9-10/21 0.8 MGAD	-2.21 LBS 5 DAYS 10/2-10/6 1.0 MGAD	-2.81 LBS 5 DAYS 10/2-10/6 1.0 MGAD	
6	-15.73 LBS 40+ DAYS 5/17-6/27 0.4 MGAD	-7.11 LBS 14 DAYS 11/20-12/4 0.6 MGAD		-2.83 LBS 5 DAYS 10/9-10/13 1.0 MGAD	-3.94 LBS 5 DAYS 10/9-10/13 1.0 MGAD	
7		-5.27 LBS 73 DAYS 1/1-3/21 0.4 MGAD		-3.76 LBS 6 DAYS 10/23-10/28 1.0 MGAD	-4.73 LBS 7 DAYS 10/22-10/28 1.0 MGAD	
8		-10.91 LBS 13 DAYS 4/15-4/29 0.6 MGAD		-7.76 LBS 8 DAYS 11/13-11/20 1.0 MGAD	-4.70 LBS 3 DAYS 11/13-11/15 1.0 MGAD	

(Continued)

TABLE C-2-9. (CONTINUED)

9	-8.07 LBS 25 DAYS 5/14-6/8 0.6 MGAD	-35.20 LBS 141- DAYS 12/23-5/14 0.4 MGAD	-11.64 LBS 58 DAYS 12/23-2/18 0.4 MGAD
10			-2.92 LBS 20 DAYS 3/5-3/24 0.4 MGAD
11			-4.90 LBS 7 DAYS 4/29-5/5 1.0 MGAD
12			-8.32 LBS 12 DAYS 5/14-5/26 1.0 MGAD
13			-5.25 LBS 7+ DAYS 6/10-6/16 1.0 MGAD

TABLE C-3-1. SEASONAL FILTER COMPARISON FOR POUNDS OF BIOCHEMICAL OXYGEN DEMAND REMOVED

RUN COMPARISON SUMMARY FOR BOD5

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
SUMMER 6/26-9/20	25.30 LBS	31.57 LBS	39.66 LBS	26.15 LBS	29.63 LBS	[illegible]3.58 LBS
FALL 9/26-12/19	62.00 LBS	51.54 LBS	17.39 LBS	52.92 LBS	35.31 LBS	3[illegible].40 LBS
WINTER 12/26-3/20	78.95 LBS	37.35 LBS	0.00 LBS	85.54 LBS	62.66 LBS	31.41 LBS
SPRING 3/27-6/19	189.26 LBS	165.72 LBS	0.00 LBS	44.66 LBS	25.91 LBS	94.78 LBS

TABLE C-3-2. SEASONAL FILTER COMPARISON FOR POUNDS OF CHEMICAL OXYGEN DEMAND REMOVED

RUN COMPARISON SUMMARY FOR COD

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
SUMMER 6/26-9/20	185.53 LBS	237.49 LBS	229.96 LBS	222.71 LBS	198.86 LBS	101.84 LBS
FALL 9/26-12/19	144.53 LBS	126.32 LBS	67.00 LBS	133.61 LBS	105.88 LBS	79.05 LBS
WINTER 12/26-3/20	262.98 LBS	134.77 LBS	0.00 LBS	278.99 LBS	199.23 LBS	101.38 LBS
SPRING 3/27-6/19	382.13 LBS	327.13 LBS	0.00 LBS	142.10 LBS	89.84 LBS	207.55 LBS

TABLE C-3-3. SEASONAL FILTER COMPARISON FOR POUNDS OF SUSPENDED SOLIDS REMOVED

RUN COMPARISON SUMMARY FOR SS

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
SUMMER 6/26-9/20	67.97 LBS	101.25 LBS	129.87 LBS	86.23 LBS	107.97 LBS	66.51 LBS
FALL 9/26-12/19	133.31 LBS	134.47 LBS	69.97 LBS	126.82 LBS	91.05 LBS	65.57 LBS
WINTER 12/26-3/20	136.03 LBS	80.67 LBS	0.00 LBS	142.10 LBS	58.77 LBS	46.67 LBS
SPRING 3/27-6/19	177.45 LBS	149.27 LBS	0.00 LBS	99.43 LBS	68.50 LBS	95.27 LBS

TABLE C-3-4. SEASONAL FILTER COMPARISON FOR POUNDS OF VOLATILE SUSPENDED SOLIDS REMOVED

RUN COMPARISON SUMMARY FOR VSS

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
SUMMER 6/26-9/20	46.32 LBS	76.57 LBS	95.37 LBS	69.90 LBS	64.72 LBS	41.78 LBS
FALL 9/26-12/19	85.78 LBS	79.03 LBS	31.14 LBS	86.52 LBS	59.85 LBS	46.58 LBS
WINTER 12/26-3/20	123.99 LBS	79.56 LBS	0.00 LBS	132.71 LBS	69.39 LBS	45.13 LBS
SPRING 3/27-6/19	130.07 LBS	112.26 LBS	0.00 LBS	68.51 LBS	50.83 LBS	72.33 LBS

TABLE C-3-5. SEASONAL FILTER COMPARISON FOR POUNDS OF TOTAL SOLUBLE PHOSPHORUS REMOVED

RUN COMPARISON SUMMARY FOR TOTAL P

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
SUMMER 6/26-9/20	3.00 LBS	2.24 LBS	3.30 LBS	2.70 LBS	2.27 LBS	1.44 LBS
FALL 9/26-12/19	1.69 LBS	2.27 LBS	1.44 LBS	1.75 LBS	0.99 LBS	0.89 LBS
WINTER 12/26-3/20	1.02 LBS	0.96 LBS	0.00 LBS	0.05 LBS	-0.68 LBS	0.55 LBS
SPRING 3/27-6/19	3.99 LBS	3.48 LBS	0.00 LBS	1.08 LBS	-0.02 LBS	1.39 LBS

TABLE C-3-6. SEASONAL FILTER COMPARISON FOR POUNDS OF ORTHOPHOSPHATE AS PHOSPHORUS REMOVED

RUN COMPARISON SUMMARY FOR O-PO4-P

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
SUMMER 6/26-9/20	2.05 LBS	1.46 LBS	1.06 LBS	0.87 LBS	0.53 LBS	-0.35 LBS
FALL 9/26-12/19	-0.05 LBS	0.45 LBS	-0.04 LBS	-0.35 LBS	-0.43 LBS	-0.24 LBS
WINTER 12/26-3/20	-0.30 LBS	0.30 LBS	0.00 LBS	-1.67 LBS	-0.73 LBS	0.20 LBS
SPRING 3/27-6/19	0.33 LBS	0.50 LBS	0.00 LBS	-0.20 LBS	-1.58 LBS	-0.56 LBS

TABLE C-3-7. SEASONAL FILTER COMPARISON FOR POUNDS OF AMMONIA AS NITROGEN REMOVED

RUN COMPARISON SUMMARY FOR NH3-N

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
SUMMER 6/26-9/20	7.31 LBS	6.58 LBS	12.40 LBS	11.48 LBS	10.33 LBS	11.09 LBS
FALL 9/26-12/19	15.51 LBS	16.48 LBS	9.46 LBS	14.94 LBS	9.45 LBS	5.11 LBS
WINTER 12/26-3/20	22.97 LBS	2.06 LBS	0.00 LBS	21.15 LBS	15.07 LBS	6.86 LBS
SPRING 3/27-6/19	10.38 LBS	7.65 LBS	0.00 LBS	8.41 LBS	8.17 LBS	5.84 LBS

TABLE C-3-8. SEASONAL FILTER COMPARISON FOR POUNDS OF NITRITE AS NITROGEN REMOVED

RUN COMPARISON SUMMARY FOR NO2-N

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
SUMMER 6/26-9/20	-0.63 LBS	-0.75 LBS	-1.24 LBS	-1.45 LBS	-1.96 LBS	0.00 LBS
FALL 9/26-12/19	-0.29 LBS	-0.75 LBS	-0.15 LBS	-0.56 LBS	-0.68 LBS	-0.11 LBS
WINTER 12/26-3/20	-0.07 LBS	-0.11 LBS	0.00 LBS	-0.67 LBS	-0.33 LBS	-0.01 LBS
SPRING 3/27-6/19	-0.03 LBS	-0.10 LBS	0.00 LBS	0.06 LBS	0.07 LBS	0.11 LBS

TABLE C-3-9. SEASONAL FILTER COMPARISON FOR POUNDS OF NITRATE AS NITROGEN REMOVED

RUN COMPARISON SUMMARY FOR NO3-N

RUN	FILTER 1	FILTER 2	FILTER 3	FILTER 4	FILTER 5	FILTER 6
SUMMER 6/26-9/20	-13.94 LBS	-21.12 LBS	-20.36 LBS	-17.43 LBS	-18.41 LBS	-20.17 LBS
FALL 9/26-12/19	-27.96 LBS	-24.04 LBS	-14.38 LBS	-18.08 LBS	-17.06 LBS	-12.93 LBS
WINTER 12/26-3/20	-25.38 LBS	-5.27 LBS	0.00 LBS	-30.32 LBS	-14.57 LBS	-5.63 LBS
SPRING 3/27-6/19	-16.70 LBS	-18.98 LBS	0.00 LBS	-4.88 LBS	-18.46 LBS	-14.39 LBS

Appendix D

1. Cost Estimate I--Total Costs For the Construction and Operation of a Two-Filter Facility.

2. Cost Estimate II--Total Costs For the Modification of an Existing Lagoon System and Operation of a Two-Filter Facility.

TABLE D-1. COST ESTIMATE I--SINGLE INTERMITTENT FILTERS (DUPLICATE FACILITIES)

Design capacity: 0.5 MGD
Design hydraulic loading rate: 0.6 MGAD (Filter area = 0.835 acre)
Locally available sand: 0.17 mm effective size @ 30" bed depth
Interest rate: 7 percent
Economic life:

- Land--100 years
- Embankment--50 years
- Pumps--10 years
- Sand--20 years
- Gravel--50 years
- Other--50 years

Initial construction cost (in place):

	Quantity	Unit Cost	Total Cost
Granular media (sand)	6,250 yd^3	\$ 4.40	\$27,500
Gravel	2,220 yd^3	\$ 4.40	\$ 9,770
6" lateral drains (10 ft. spacing)	7,380 ft	\$ 1.00	\$ 7,380
Ductile iron pipe	500 ft	\$ 9.50	\$ 4,750
Pumps (3 hr. application, 1 pump for each filter, plus 1 standby, 2800 gpm and timer, 30 ft TDH)	3	\$3,200.00	\$ 9,600
Excavation and embankment (Slopes--3:1 interior, 2:1 exterior; lined with clay type impervious material; 10' wide at top of dike)	13,828 yd^3	\$ 1.00	\$13,830
Building	1	\$2,000.00	\$ 2,000
Distribution system	2	\$1,000.00	\$ 2,000
Pipe distribution	1,000 ft	\$ 2.00	\$ 2,000
Land	6 acres	\$1,000.00	\$ 6,000
Total Capital Cost			\$84,830

(Continued)

TABLE D-1. (CONTINUED)

Amortization:

Land: $6000 x 0.07008 = $ 420
Pipe: ($7380 + 4380 + 2000) 0.07246 = $ 997
Sand: ($27,500) 0.09439 = $2,596
Gravel: ($9,770) 0.07246 = $ 708
Pumps: ($9,600) 0.14238 = $1,367
Embank.: ($13,830) 0.07246 = $1,002
Building: ($2,000) 0.07246 = $ 145
Dist. Sys.: ($2,000) 0.07246 = $ 145

$7,380

Annual Operating and Maintenance Costs

Maintenance cost: 1,000/yr
Manpower cost: (1/4 man-year @ $10,000/yr) 2,500/yr
Power: 22 PH or 16 KW
16 KW (3 hr/day) (365 days/hr) = 17,520 KW-hr/yr
17,520 KW-hr/yr ($0.03/KW-hr) = 526/yr

Total O & M Costs $4,026/yr

Total Annual Costs $11,406/yr

Cost per 10^6 gallons

With federal assistance (75% of construction cost paid by federal government, remaining 25% financed at 7% for 20 years)

$84,830 (0.25) (0.09439) = $2,002
O & M $4,026
$6,028

$$\frac{\text{Total Annual Cost}}{\text{Total Annual Flow}} = \frac{\$6,028}{0.5\ \text{MGD}\ (365\ \text{d})} = \underline{\$33/\text{mg}} \text{ or } \underline{0.03/1,000\ \text{gal.}}$$

Without federal assistance

$$\frac{\text{Total Annual Cost}}{\text{Total Annual Flow}} = \frac{\$11,406}{0.5\ \text{MGD}\ (365\ \text{d})} = \underline{\$62.5/\text{mg}} \text{ or } \underline{0.06/1,000\ \text{gal.}}$$

TABLE D-2. COST ESTIMATE II--MODIFICATION OF EXISTING LAGOON SYSTEM TO ACCOMMODATE INTERMITTENT SAND FILTER IN ONE OF EXISTING CELLS (DUPLICATE FILTERS CONSTRUCTED)

Single Filter System

All considerations would be the same as Estimate I with the exception being the elimination of land costs and approximately 75% of the embankment requirements.

Total Capital Costs = \$84,830 - (0.75) (13,830) - 6,000
= \$68,457

Amortization = \$7,380 - (0.75) (1,002) - \$420
= \$6,208

Total O & M = \$4,026

Total Annual Cost = \$10,234

Cost per 10^6 gallons

With federal assistance (75% of construction cost paid by federal government, remaining 25% financed at 7% for 20 years)

\$68,457 (0.25) (0.09439) = \$1,615
O & M = \$4,026
Total Annual Cost = \$5,641

$$\frac{\text{Total Annual Cost}}{\text{Total Annual Flow}} = \frac{\$5{,}641}{182.5 \text{ mg}} = \underline{\$31/\text{mg}} \text{ or } \underline{\$0.03/1{,}000 \text{ gal.}}$$

Without federal assistance

$$\frac{\text{Total Annual Cost}}{\text{Total Annual Flow}} = \frac{\$10{,}234}{182.5 \text{ mg}} = \underline{\$56/\text{mg}} \text{ or } \underline{\$0.056/1{,}000 \text{ gal.}}$$

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-600/2-78-033

2.

3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE
SEPARATION OF ALGAL CELLS FROM WASTEWATER LAGOON EFFLUENTS; Volume I: Intermittent Sand Filtration to Upgrade Waste Stabilization Lagoon Effluent

5. REPORT DATE
June 1978 (Issuing Date)

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Steven E. Harris, D.S. Filip, James H. Reynolds, E. Joe Middlebrooks

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Utah State University
Utah Water Research Laboratory
Logan, Utah 84322

10. PROGRAM ELEMENT NO.
IBC611, SOS#3, Task D-19

11. CONTRACT/GRANT NO.
68-03-0281

12. SPONSORING AGENCY NAME AND ADDRESS
Municipal Environmental Research Laboratory--Cin.,OH
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

13. TYPE OF REPORT AND PERIOD COVERED
Final 1973-1977

14. SPONSORING AGENCY CODE
EPA/600/14

15. SUPPLEMENTARY NOTES
Project Officer: Ronald F. Lewis 513/684-7644

16. ABSTRACT

A project to evaluate the performance characteristics of the intermittent sand filter for polishing lagoon effluents was conducted. Techniques described in the literature for summer and winter operation were applied to determine if filter effluents would consistently meet PL 92-500 requirements.

It was found that effluent quality is affected by temperature and hydraulic loading rate variations, but that effluents meet very stringent water quality standards. Effluent values of less than 10 mg/ℓ BOD_5, 10 mg/ℓ SS and 5 mg/ℓ VSS were consistently met. Organic nitrogen conversion and excellent nitrification were also found to take place within the filters.

It was concluded that the intermittent sand filter is an ideal process for upgrading lagoon effluents.

This report was submitted in partial fulfillment of Contract No. 68-03-0281 by Utah State University under the sponsorship of the U.S. Environmental Protection Agency. Experimental work described and discussed herein covers the period of July, 1974, to July, 1975.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Waste treatment *Lagoons (ponds) *Sand filtration *Algae Effluents--filtration	Intermittent sand filtration Algae removal	13B

18. DISTRIBUTION STATEMENT
Release to Public

19. SECURITY CLASS *(This Report)*
Unclassified

20. SECURITY CLASS *(This page)*
Unclassified

21. NO. OF PAGES
194

22. PRICE
A09- A01

EPA Form 2220-1 (Rev. 4-77)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1978 — 757-140/1306